

Mapping health on the Internet: A new tool for environmental justice and public health research

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Abstract

This paper examines the prospects for integrating Internet platform GIS or 'web-GIS' into environmental justice and related public health research. Specifically, we document the development of a web-GIS created for investigating relationships between health, air quality and socioeconomic factors in Hamilton, Canada. After development of the web-GIS site, we assembled a focus group of public health professionals to test functionality and render opinions about the potential of the site and geographic information in their program implementation. Results show overwhelming support for the further integration of GIS into public health practice. The results also underscore the potential of web-GIS to alleviate concerns of cost and data availability that often limit the use of GIS in community debates centred on environmental justice issues.

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Introduction and overview

The environmental justice movement has relied heavily on environmental and health science information to build the case that minority and socially disadvantaged groups bear disproportion-

ate burdens of environmental contamination (Esnard et al., 2004). From the earliest studies documenting alleged injustice (United Church of Christ, 1987), scientific synthesis about potential toxic risks has contributed to and been symbiotically aided by community activism under the environmental justice construct (see Tyson et al., 1998 for a review). More recently, communities of concern that may bear the costs of unequal environmental risks have shown an interest in accessing environmental information on an ongoing basis, through the World Wide Web (WWW) and other related technologies (Louis and Magpili,

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2002). Likewise, public health officials have become more attuned to the potential for environmental disparities and their connection to health inequalities that run along social gradients and racial lines (Bass, 1998). Geographic Information Science and related methods in spatial statistics can help to inform communities and public health officials about the potential environmental health risks and the inequalities in those risks (Theseira, 2002).

Technologies such as the WWW and Geographic Information Systems (GIS) have been integrated into the activities of many health organizations (Jadad and Gagliardi, 1998; Yasnoff and Sondik, 1999; Croner, 2000). Although promising, problems have risen with public health organizations and community groups wanting to incorporate GIS methods and technology into their standard programs. Many organizations want to use GIS, but lack the resources and expertise to build in-house GIS capacity (Leitner et al., 2000; Sieber, 2000). Internet mapping or 'web-GIS' can assist in alleviating this problem by providing GIS tools on an Internet platform with relatively low costs and training requirements in comparison to purchasing and using stand alone GIS systems (Wong and Chua, 2004). Costs are further reduced through the sharing of data in the web-GIS environment. This paper summarizes a multi-year research program aimed at developing a web-GIS site for exploring relations between air pollution, socioeconomic status and respiratory health in Hamilton, Canada, an industrial city of approximately half a million people at the western end of Lake Ontario (see Fig. 1 for a locator map).

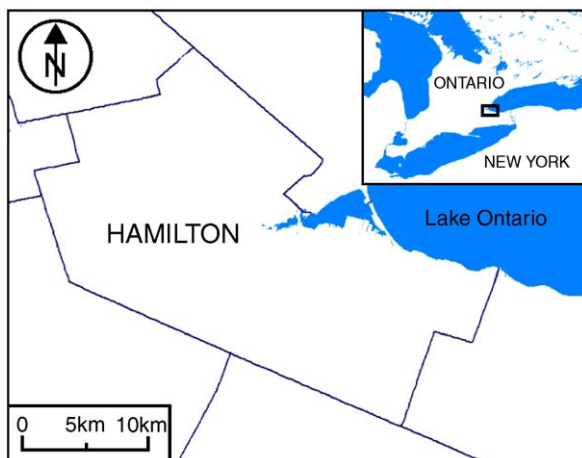


Fig. 1. A map of the study area, Hamilton, Ontario Canada.

Rationale for web-GIS

Researchers have utilized GIS and related spatial statistics in many health studies (see Gatrell and Loytonen, 1998; Moore and Carpenter, 1999 and Jerrett et al., 2003 for reviews). GIS can be defined as a spatial analysis system for the organization, storage, transformation, retrieval, analysis, and display of data (DeMers, 1997; Aronoff, 1989) where location is considered important (e.g., the incidence of a specific health condition or disease in relation to a pollution source). Representation and analysis of disease incidence data in map form has now established itself as a basic tool within the realm of public health and environmental justice (Lawson, 2001; Jerrett et al., 2003). The ability to plot the risk of disease cartographically gives public health officials better information on where to target programs of disease prevention. This same ability to plot risk can be built upon by relating risks to variables such as social characteristics, pollution and respiratory health, which can then be used as environmental justice indicators (Jerrett et al., 1997).

In addition to mapping disease (Anyamba et al., 2001; Miller, 2001), public health officials and epidemiologists map suspected disease predictors. Studies have mapped immunization rates (Cowell and Cowell, 1999), health care access (Phillips et al., 2000), sociodemographic variables (Selvin et al., 1998; Blake and Bentov, 2001; Burstrom et al., 2001), pollution concentrations (Burnett et al., 2001; Jerrett, 2001; Pikhart et al., 1997, 2001), and socioeconomic distributions of pollutants (Buzzelli et al., 2003; Jerrett, 2001; Maantay, 2002). The mapping of disease predictors in public health assists in predetermining potential problem areas, which inform surveillance and intervention programs. Recent efforts focus on producing maps that show concordance between socially disadvantaged areas and high environmental risks (Holton, 2004).

Does a demand for Web-GIS technologies exist?

In 1997 the Canadian National Health Surveillance Infrastructure (NHSI) was launched to demonstrate the use of new information technologies and Internet-based tools to improve public health surveillance. The NHSI consists of pilot projects aimed at four goals: (1) improving access to existing databases, (2) facilitating the linkage of databases, (3) providing an affordable evidence-based tool for

analysis and presentation of information, and (4) ensuring timely access to health information. To test the feasibility of these goals, NHSI launched a survey to determine the use and concerns of information technologies and Internet-based tools among health professionals (Bédard et al., 2000).

While the survey associated with the pilot project illustrated interest of public health professionals in GIS and related mapping techniques, the authors concluded that GIS was underutilized in the health field. Approximately 96% of respondents felt spatial information was not being used to its full extent within their organizations. Many respondents felt that the use of spatial data was just in the beginning stages, but concerns that may slow growth were exposed, such as a lack of resources, capacity to train staff, and data quality that may be addressed by the users of web-GIS (Haklay and Tobon, 2003). Allowing public health offices to access a web-GIS system at little or no cost coupled with a diligent effort towards data sharing would partially address these concerns (Bédard et al., 2000).

Survey results collected in January of 1999 by the Information Network of Public Health Officials (INPHO) in the United States revealed that while several Public Health departments had years of successful experience in GIS initiatives, some departments were only beginning to use GIS in their projects (Yasnoff and Sondik, 1999). From this survey several key issues surfaced. In particular, the findings indicated a demand for web-enabled GIS. Web-GIS has the potential to allow those in public health to have a standard platform to display spatially referenced data and provides a platform for the training of public health officials to use GIS and apply spatial analysis through on-line tutorials.

Problems with GIS technology relate to time lost learning the technology and data issues which arise in implementation (Nedovic-Budic, 1998). Instead of using GIS as a tool to solve a problem or put forth a new hypothesis, researchers spend too much time learning the technology (Lloyd, 2001). Web-GIS may reduce time spent learning spatial technologies, enabling researchers and environmental justice activists to focus on substantive questions.

With major concerns revolving around cost and data quality, similar to the Canadian findings, the American study demonstrated an unmet demand for web-GIS. A web-GIS system has the potential to bring GIS technology to public health professionals and community groups at minimal cost with no prior expertise in spatial analysis.

Methods

This research program broadly followed the cascade development model, a common procedure in software development (Babich, 1986). Briefly, this model as applied in our study includes five major components: (1) a systematic review of existing sites; (2) a software selection evaluation; (3) compilation of the data base support for the developed site; (4) a focus group and survey based on a beta version of the site; and finally, (5) refinements to the site based on user feedback. We first attempted to identify the current state of development and current user needs. Findings from the scholarly literature, user needs focus groups and surveys fed into our site design. At the completion of the final step of the model (enhancements based on testing) the improvements must be subjected to needs assessment based on additional testing.

Systematic site review

To examine the current status of web-GIS, a review of 30 existing applications was conducted by testing a sample of current applications against a set of 21 criteria organized under five broad categories: 'Metadata,' 'Technical Aspects,' 'Data,' 'Cartographic Capabilities,' and 'Data Analysis' (Table 1) that the earlier NHSI surveys had identified as important (Bédard et al., 2000).

Software evaluation

There are several Internet mapping and web GIS applications that might have been used to support this project, both open and closed source. These include ESRI's ARCIMS, MapInfo MapExtreme, and MapObjects Internet Map Server. We reviewed and tested ESRI's Internet Map Server (ARCIMS), a leading commercial program available for distribution of spatially referenced data and GIS functionality via the Internet, and an open source program called 'Mapserver.'

ARCIMS is closed-source software (where the source code is not available for manipulation to the user and development community). Benefits of using ARCIMS software include out of the package implementation, large user community, and ESRI support. This software also had disadvantages, including: (1) large computational demands, (2) the need for downloading an Internet plug-in to

support the system, and (3) relatively high purchase and operating costs.

This initial evaluation of available commercial software resulted in a search for other suitable programs comparable to ARCIMS that have lower cost, which would be capable of running on inexpensive computers, likely to be used by public health and environmental justice groups. This evaluation research and initial testing led to a decision to evaluate the open-source MapServer software (MapServer, 2004). Open source software is available at zero or minimal costs with the source code being available for manipulation (Anderson and Moreno-Sanchez, 2003).

The University of Minnesota (UMN) in cooperation with NASA and the Minnesota Department of Natural Resources (MNDNR) originally developed MapServer. In addition the MNDNR and the Minnesota Land Management Information Center (LMIC) made additional enhancements. Current development is funded by the TerraSIP project, a NASA-sponsored project between the UMN and a consortium of land management interests. While MapServer can use data developed by standard ESRI products (such as ArcView and ArcGIS), it allows greater scope for development of additional functionality than ARCIMS. MapServer software is a free download from the MapServer website (MapServer, 2004), which may encourage future use of the tool by local public health and environmental justice groups. MapServer does not require a client side program aside from an Internet browser for maps to be viewed (ARCIMS requires a plug-in installation of the ArcExplorer application). The ability to view maps without having to download plug-ins or install other client-side software may facilitate work in network environments where installation of software is restricted to network administrators. A considerable benefit of developing an application with MapServer is the availability of the 'list serve', an on-line newsgroup that allows the developer to e-mail a large group of people with any development questions at no cost. This type of service is commonly available for software and was used successfully and often during the duration of this project. Because we targeted public health and community groups as the main users of our site and potential adopters of the technology, we selected MapServer as our development platform. The potential issues with using MapServer software revolve around computer expertise and the potential costs this expertise may bring. For the purposes

of this project the costs are minimal because the expertise does not need to be purchased. In the Public Health sector computer programming services may need to be purchased, but the costs do not have to be a burden for one agency as a group with similar interests can split costs. This method of implementation was successfully accomplished in a related project (Maclachlan et al., 2004).

Data used for the Web-GIS site

The NHSI identified access to relevant, reliable and current data on health outcomes and risk factors as a high priority. Thus, the data used for this project allows the user to explore the relationships between asthma symptoms, smoking rates, pollution levels, and socioeconomic status. The user will be viewing the geographic area of Hamilton, Ontario, an industrial city with the highest asthma prevalence in Canada. The asthma and smoking rates were obtained through the results of a questionnaire by the International Union against Tuberculosis and Lung Disease (Burney et al., 1987; Burney, 1994). In the absence of a universally accepted definition of asthma, the survey represented the burden of asthma in the population is best represented by the distribution of asthma symptoms and bronchial responsiveness (Manfreda, 2001). The prevalence of asthma symptoms, attacks and medication are questioned rather than 'Have you ever had, or have, asthma.' Questions concerning symptoms of respiratory problems, non-asthma respiratory symptoms, smoking, occupational exposure to dust, fumes and gases and residential history are also included in the questionnaire. Random digit dialling was used to identify eligible individuals. For the city of Hamilton, a random sample of about 1800 telephone numbers was used. The individual results obtained from the sample were calculated into rates at the census tract level of geography and are documented elsewhere (Jerrett et al., 2003). Socioeconomic indicators at the census tract level of geography were available from Statistics Canada 1996 census. Pollution data was collected at fixed-site ambient monitors operated by the Ontario Ministry of the Environment (MOE) throughout Hamilton. The data were interpolated to give a continuous surface across the city. Table 2 lists all variables utilized in this project.

Table 2
Categorized variables used in the web-GIS site

Pollution variables	Census variables	Survey variables
Particulate matter	1996 population	Asthma rates
Sulphur dioxide	Average dwelling value	Smoking rates
Nitrous oxides	Gini coefficient	

Organization of the focus group

To test the web-GIS site and administer a questionnaire to obtain user feedback, a focus group was held November 2, 2001 at McMaster University in Hamilton, in partnership with the Central West Health Planning Information Network (CWHPIN), one of five Health Intelligence Units established by the Ontario Ministry of Health and Long-Term Care to improve local public health. CWHPIN is a partnership made up of seven public health units and four district health councils. CWHPIN offers informational, analytical services and policy guidance to participating public health organizations across Ontario (CWHPIN, 2004).

Invitees to the focus group consisted of Public Health officials from the area of Southern Ontario. The full day focus group meeting, which had 19 attendees from an initial list of 27 invitees, began with presentations intended to familiarize respondents with spatial analysis in Public Health, web-GIS, and other applications. Following the presentations demonstrations of both the newly created web-GIS prototype site and the on-line tutorial created to accompany the site were shown to the attendees. With the presentations and demonstrations completed, the focus group participants had the opportunity to explore the web-GIS site. While the participants were testing the site the presenters and four student assistants stayed to answer any questions people had about the presentations or the site itself. Following the site exploration, participants were asked to complete a survey with questions concerning their computer knowledge, general opinions of web-GIS, specific views of the prototype site, and the focus group itself.

Results

Systematic site assessment

An overview of the results of the study is separated into the five evaluation subgroups:

Metadata; Technical Aspects; Data; Cartographic Capabilities; and Data Analysis (see Table 1 for a summary of the evaluation subgroups and the results for each of the sites). Sites based solely upon health data are difficult to locate, either because they are housed behind a firewall that prohibits access to the general public or because they simply do not exist. Thus, the review was not limited to sites that dealt exclusively with health data; those based on potential health predictor data were also included (e.g., pollution levels). All site addresses appear in the Appendix.

Metadata is data that describes the ‘who, what, and where’ of a geospatial dataset (Clarke, 2003). Of the criteria subsets this was the most complete with 77% of total criteria. ‘Authorship attribution’ is the criterion that ensures the person or association responsible for the creation of the site is explicit had the highest matching rate at 97%. This was expected, as creators of a website would want to be recognized for funding and promotion purposes. The majority of reviewed sites disclosed their funding (70%) and the currency of data (73%). Within this subset the least matched criterion is attribution of sources for data (67%). Incomplete metadata means the site is of limited use to external researchers because in many instances, not knowing the data collection and implementation history inhibits future use. This finding emphasizes the need for clear and complete metadata in the development of future sites.

In evaluating the technical aspects, the sites reviewed matched 65% of the total criteria. The ‘Site Accessibility’ criterion was met by 97% of sites tested although this result is somewhat misleading. A site failed the criterion if any aspect was password protected. For example, if a password was needed to download data this would warrant the site failing the criterion. While few sites had aspects that were inaccessible, there were sites which were completely inaccessible. These sites were not included in this study because other criteria could not be tested, indicating our results would underestimate the problem of accessibility. ‘Ease of Navigation’ is the most subjective criterion and was based on our qualitative experience with using the site. The criterion was deemed as acceptable if the mapping could be accessed quickly from the home page and all information related to the maps was easy to access. Recognizing the limits inherent in this criterion, 63% of the sites could be navigated easily. An example of this would be not being able to

access metadata directly from the map-viewing page.

The three criteria that measured time are discussed in the 'Technical Aspects' subset. The 'Speed of Site Start Up,' 'Map Uploading Time' and 'Query Process Time' criteria all matched 50% of the time. Server congestion at the server end of the testing cannot be controlled. To minimize this, each site criterion was tested from the same computer at approximately the same time of day (Pentium 3 600 Mhz between 3:00 and 6:00 pm). After testing all sites the average was taken, and those below the average matched the criteria. Numerous sites did not have query capabilities. Consequently these cases are defined as not applicable (N/A). The average speed of start up was 6.7 s, map uploading time 7.4 s, and query processing time 10.7 s.

The 'Data' subset matched 44% of the total criteria. The majority of sites (87%) have links to other sites, which may assist users to easily locate more information on a topic of interest. Half (50%) contained the ability to search themselves. The ability to search within the site, which houses the web-GIS is not a popular function. Information on how site designers handled issues of confidentiality were rarely explicit (20%) and the ability for data to be downloaded (20%) was also uncommon. With there being a shortage of desktop GIS capabilities in public health agencies, the ability to download data is not crucial but may be important in the future if GIS software becomes more readily available.

The criteria for 'Cartographic Capabilities' had a 24% matching rate. The Cartographic Capabilities subset is a technological intensive set of criteria. The ability to produce graphs (3%) and alter colour schemes (7%) are not typical web-GIS functions. Approximately 63% of sites had capacity for scale adjustments (i.e., zooming in or out).

The 'Data Analysis' subset matched 12% of the total criteria. Only two criteria, 'Boolean Queries' and 'Interactive Overlays,' were matched with any regularity, at 23% and 30%, respectively. Of the final three criteria 'Re-classing Data', 'Pattern Recognition', and 'Advanced Regression' only one had any matches. The ability to re-class data was found in only 7% of sites.

Examination of the current state of the technology influenced the design of the web-GIS health site for Hamilton. Compared to the overall state of the technological capability in GIS, web-GIS applications appear underdeveloped. The majority of web-GIS sites are technically sound and contain

adequate metadata allowing the user to critically assess the data being viewed. These are key issues if the technology is to be used properly, but they are also the easiest to implement. Less than half the sampled sites had the ability to query or overlay data. While it was not a specific criterion, none of the web-GIS applications allowed for multi-criteria queries. This was the most striking gap in functionality that could be effectively implemented in the time span of our study. With only one exception, the sites reviewed offered no advanced overlay or statistical capabilities.

Development of the beta site

To create an effective web-GIS site, we had to develop a site map that included functionality useful to the intended audience. Functionality used to explore the map and data mimic those used in a standard GIS (Plewe, 1997). This allows for users with any exposure to GIS to become quickly familiar with the functions. People with little or no prior GIS exposure may learn the functionality through 'trial and error' or, more effectively, the accompanying on-line tutorial. Keeping functionality simple to use, yet advanced enough to contribute to the intended audience, was a major challenge. The NHSI user needs assessment demonstrated that respondents would like the ability to explore and query spatial data, but they worry about employing vast amounts of time and resources in terms of software and training. Basic functionality built into the prototype used in map exploration are the 'zoom in,' 'zoom out,' 'pan,' and 'view full map' tools. The second step involved adding data exploration tools. Data exploration tools include: (1) several 'layers' of spatial information and the capability to turn them on and off; (2) the ability to change the background from a uniform colour to a choropleth map using different, predetermined variables (Fig. 2); (3) allowing the user to obtain information for a specific area of interest through a query button (Fig. 3); (4) being able to input numbers into a query system permitting the user to locate areas on the map that match all the inputted criteria; and (5) develop a tool allowing the user to locate the census tract containing an inputted postal code. Fig. 4 illustrates the result of a user inputting variable ranges of interest. (The site may be viewed and used at <http://healthgis.mcmaster.ca>.) The functionality created required use of the programming languages

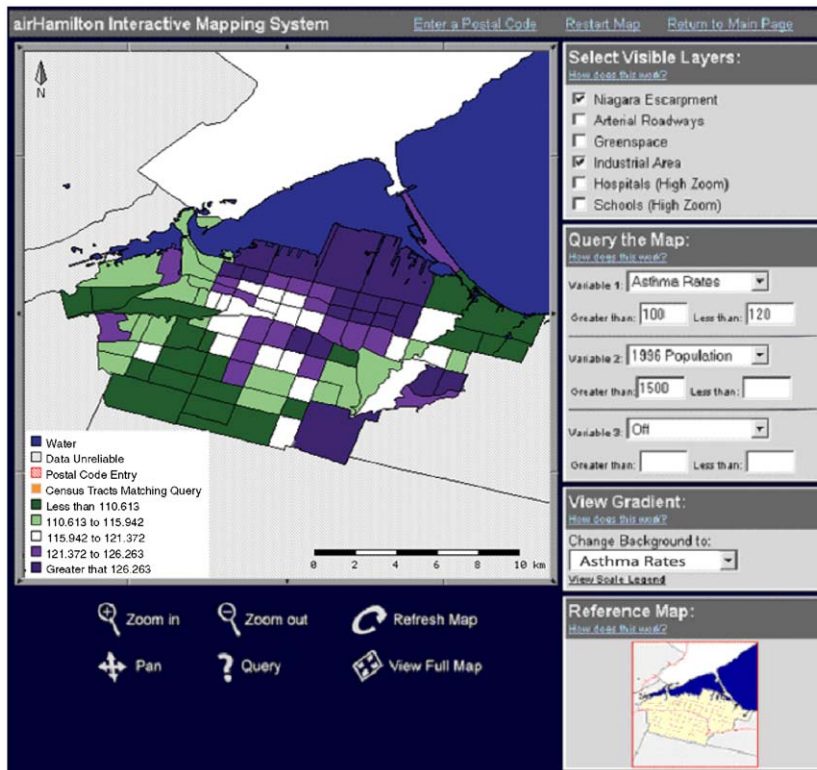


Fig. 2. The appearance of the map when the background is changed from 'default.' The example used in the figure is 'Asthma Rates.'

Hypertext Markup Language (HTML), JavaScript (JS), Microsoft (MS) Common Gateway Interface (CGI), and Hypertext Preprocessor (PHP) (PHP, 2002).

Focus group results

After experimenting with the prototype site and completing the on-line tutorial, the focus group was given a survey to determine their thoughts on subjects covered during the day. The results of the survey are a biased sample because only those who felt the technology might be of interest to them attended the focus group. This is deemed acceptable in this instance as the majority of those who attended the focus group had little or no experience using web-GIS. Questions were directed at assessing basic knowledge concerning GIS and perceptions of how this technology could help in decision making (Table 3). Surprisingly, most participants believed they had a good understanding of GIS, with 62% rating their understanding as "good" or "excellent". As the complexity of the technology increases, the perceived understanding decreases. When asked if they had a good understanding of Internet Map-

ping, only 42% of respondents agreed. The downward trend of understanding continued with only 38% of respondents having a good understanding of on-line analytic processing (OLAP). The phrase OLAP is a relatively new concept and refers to an information structure allowing analyst to have flexible access to data and dynamically explore relationships between summary and detail data (Scotch et al., 2004).

While the understanding of GIS and GIS-related technologies is not constant among public health professionals, most from the focus group believed that the technologies could assist them with their work. To the statement 'I think using spatial information in my work could help me do my job better,' 100% of respondents agreed. Having a high proportion of respondents considering spatial information as a potential benefit may have resulted from numerous recent papers in public health journals illustrating how spatial data contributed to the solving of a problem (e.g., Grossman-Garber et al., 1999) or from the positive impression of the beta website.

Given the visibility of GIS in public health fields, strong support for the use of spatial data was

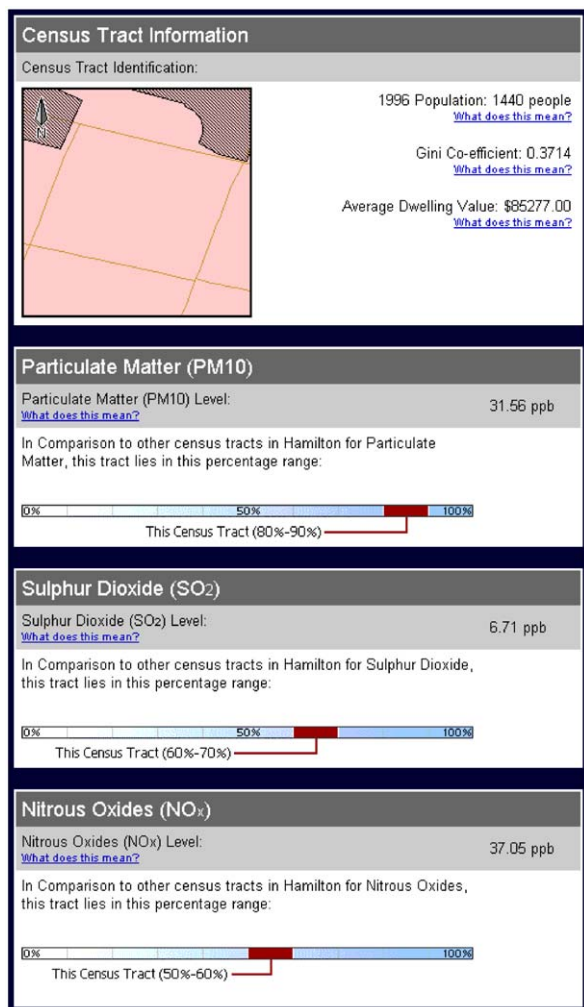


Fig. 3. The resulting information received when a query of a single census tract is performed.

expected. It was still surprising to find that such a high percentage (100%) agree that Internet mapping could help them in their work. With spatial information being an integral element of Internet mapping technology we would expect at most only those who believed spatial information would be beneficial to their work would also be as positive with Internet mapping.

Respondents were asked to agree or disagree with eight different statements to prompt consideration of the potential benefits of Internet mapping. The percentage of people who 'strongly agree' or 'agree' can be seen in Table 4. Of the eight statements, the ability to perform advanced statistics had the lowest rate of agreement with only 69%. Many focus group attendees may have little background knowl-

edge of advanced statistics, thus explaining this result. Conversely, it may reflect the generally low demand for this type of analysis in public health practice. The ability to produce paper maps was the second lowest rated benefit with 75% of users agreeing. Most of the respondents communicated that increased access to maps and the ability to share data was vital, noting a paper map is one of many ways to accomplish this objective. Again, 100% of respondents believed that the ability to explore spatial relationships was a benefit of Internet mapping.

In an attempt to understand the respondents' perceived problems with Internet mapping technology, they were questioned on eight potential shortcomings (Table 5). The responses reinforced results of the NHIS user needs survey and those found in the literature. Over half of the respondents agree that 'Limited Data', 'Cost Involved', 'Access to Data', and 'Staff Resources' are potential problems. The similarity of all these problems is data or cost in either financial resources or time. This result is consistent with past research (Gosselin et al., 2000). No other potential problem was agreed upon by more than 33% of respondents. Just over 20% felt that Internet mapping was difficult to use based on their limited experience with the site. Considering 82% of respondents found 'Ease of Use' a potential benefit of Internet mapping, it is reasonable to expect approximately 18% would see difficulty as important.

In addition to determining the perceived benefits and problems with web-GIS technology, we also sought to understand potential uses of this technology. By determining what public health professionals may use the technology for, future improvements may be tailored to suit their needs. The results indicated how this technology would be used. The majority of respondents (83%) felt that the technology could be used for data visualization and collaboration among colleagues. Slightly fewer respondents (78%) agree that the tool would be used for data exploration with spatial overlays and data analysis. These results describe a general trend suggesting public health professionals would like to use this technology mainly for the purposes of cartographic visualization.

Participant views concerning the site itself were also questioned. The first six questions of the section were based on thoughts and issues concerning the health web-GIS site. The first three questions, 'I found the on-line tutorial helpful', 'The site is

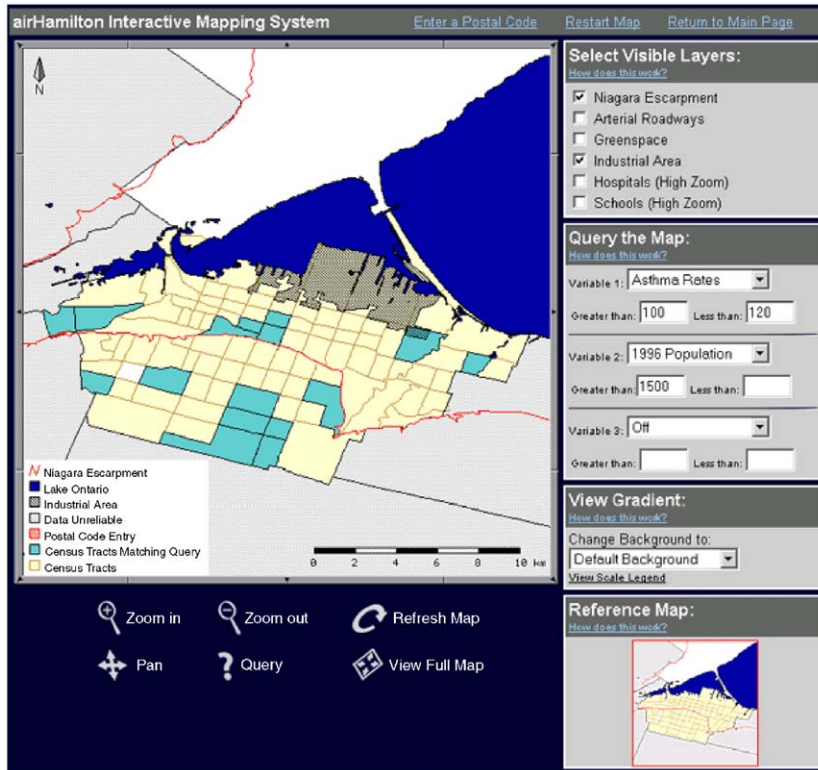


Fig. 4. The result of performing a multi-level query on the web-GIS site.

Table 3
Response to introductory survey questions

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
I have a good understanding of GIS/digital mapping	26.3	36.8	26.3	10.5	0
I have a good understanding of on-line analytic processing (OLAP)	5.2	31.6	10.5	15.7	36.8
I have a good understanding of Internet mapping	10.5	31.6	15.7	36.8	5.2

Table 4
Responses to the survey question ‘I see the following potential benefits of internet mapping’

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
Increased access to maps	68.4	26.3	5.3	0	0
Increased access to data	52.6	36.8	10.5	0	0
Ability to share data	47.4	42.1	10.5	0	0
Ability to produce paper maps	47.4	26.3	26.3	0	0
Ease of use	68.4	15.8	15.8	0	0
Explore spatial relationships	68.4	31.6	0	0	0
Perform cluster analysis	47.4	36.8	15.8	0	0
Perform advanced statistics	26.3	42.1	21.1	5.3	5.3

Table 5
Responses to the survey question 'I see the following potential shortcomings of internet mapping'

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
Limited data available	15.8	36.8	21.1	21.1	5.3
Difficult to print maps	11.1	50.0	27.8	11.1	0
Difficult to pinpoint an area	5.6	16.7	38.9	33.3	5.6
Difficult to use	5.6	16.7	27.8	44.4	5.6
Limited analytical capabilities	11.1	22.2	38.9	11.1	16.7
Cost involved in startup	5.9	47.1	23.5	17.6	5.9
Access to data	5.6	50.0	22.2	22.2	0
Staff resources	27.8	33.3	16.7	22.2	0

easy to use', and 'The site was intuitive in its use' allow the respondent to decide if a lot of time would be needed to learn how to use the site. Learning time positively relates to cost in terms of salary and lost opportunities. Reaction to these questions was positive, with 79% of people finding the on-line tutorial helpful and 95% feeling the site was intuitive and easy to use. Whether such results would be replicated in a setting away from the designers and sponsors of the site is questionable, but the high positive response indicates that many users would find the site navigable.

To test opinions on the aesthetics of the site, the survey questioned the colour scheme and design. Fully 100% of respondents agree that the site design and layout were appropriate. This bodes well for improvements in the site as adding functionality to the technology is a challenge and to completely alter the site design would be extremely time consuming. Fewer respondents agreed that the site used an appropriate colour scheme. While 84% of users agreed with the colours (a purple-green dichromatic), some recommended traditionally accepted colour schemes such as red to blue (with red representing a high risk area). This scheme was reviewed but rejected because the red may be unduly alarming for public audiences and indistinguishable by people with colour blindness (Arden et al., 1999; Brettel et al., 1997). The purple to green scheme used was chosen based on a review of this same issue in the literature (Brewer et al., 1997; MacEachren et al., 1998). Using the research to create the colour scheme, the program Vischeck (2004) was used to test the site. Vischeck's colour vision model allows for simulation of how the world looks to people with various sorts of colour vision deficiency. Basic experiments with Vischeck demonstrated that the current choice of colours can

sufficiently be differentiated by those with colour vision deficiencies. While the appearance of the site does change to users with various types of colour blindness, different layers and classifications are still distinguishable.

The greatest concern with the site in this line of questioning was allowing the public to access the information. Only 42% of respondents agree that there would be no problem with allowing full public use of the site. The tension between privacy and public health benefits appears to permeate the Internet mapping literature (Croner, 2000), and this tension may reflect broader debates about access to information for lay groups, including those involved in environmental justice (Table 6).

The existing functionality of the site was well received (Table 7). Simple functionality such as overlaying different layers and zooming in and out was viewed as beneficial by 100% of respondents. The ability to query census tracts and perform multi-criteria queries was slightly less accepted with 95% approval. Locating a census tract by postal code was the least appreciated (85%). The positive impression of the existing functionality demonstrates the importance of supporting site development with review of existing sites, user needs, and cartographic literature.

The last section of the survey questioned the perceived value of the focus group and potential future use of web-GIS technology. In both instances the results were favourable. The focus group was deemed useful by 94% of those who attended. To the question, 'Assuming that a full set of data pertinent to my geographic region is available, I would use Internet mapping in the next year,' 94% of respondents agreed. This indicates that prospective users see value in this technology. Reinforcing this observation is the result showing that 100% of

Table 6
Responses to the survey question 'I have the following thoughts about the prototype itself'

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)	Don't know (%)
I found the on-line tutorial helpful	15.8	63.2	10.5	0	0	10.5
Easy to use	36.8	57.9	5.3	0	0	0
Intuitive in its use	26.3	68.4	5.3	0	0	0
Appropriate colour scheme	21.1	63.2	10.5	0	5.3	0
Layout was appropriate	10.5	98.5	0	0	0	0
No problem in full public use	10.5	31.6	31.6	5.3	10.5	10.5

Table 7
Responses to the survey question 'I feel the following functionality of the prototype is useful'

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
Ability to look up postal code	47.4	36.8	10.5	5.3	0
Overlay different layers	73.7	26.3	0	0	0
Zoom in/ zoom out	63.2	36.8	0	0	0
Query single census tract	63.2	31.6	5.3	0	0
Multi-level query	84.2	10.5	5.3	0	0

respondents felt confident that they could effectively use an Internet mapping system.

Conclusions

This paper documents the creation of a web-GIS site for exploring associations among air pollution, socioeconomic status and respiratory health. While exploratory due to the small sample size and the selection processes, the focus group results demonstrate that the majority of target users can have their needs met on a limited budget. This project relied on open source software. The web-GIS site was created by people working in the field of geography, not computer science, and this suggests the open source software should be accessible to people working outside purely technical fields. Interestingly, key barriers lie largely outside the realm of the technology and have to do with access to data and confidentiality.

The concepts of confidentiality and data sharing are important to the future feasibility of web-GIS. There are numerous methods of protecting computers from both physical and virtual theft, but the only infallible technique is to eliminate data that could potentially violate an individual's confidentiality on any computer connected to the Internet.

Data sharing is an imperative concept for the future development of web-GIS. Using the data resources of numerous Public Health agencies together in one web-GIS system will further reduce total costs.

This project offers a glimpse of what might be the future of GIS in public health and environmental justice. Web-GIS technologies can be achieved with minimal costs and the opportunity of an increased user pool is evident. Numerous studies show that public health officials and environmental justice advocates throughout North America want more access to spatial data, and web-GIS can provide an effective way to meet that demand. Likewise, the technology offers an affordable means of giving community groups concerned with environmental justice issues the ability to prepare their own analyses and produce educational maps.

The increased availability of data will further movements of environmental justice at both the professional public health and community group levels. With more data being readily available in an effective format for public health officials they can quickly investigate potential instances of environmental injustice. Increasing the availability of neighbourhood socioeconomic, health, and environmental characteristics will allow individuals to obtain the knowledge needed to make informed

decisions concerning their own health risks and may prompt collective action to equalize the burden of environmental health risks.

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Appendix

A listing, including the web address, of all the web-GIS sites evaluated to create Table 1 are shown in Table A1.

Table A1

Site*	Web server**	Web address	Last cited
1	The University of Leeds	http://www.ccg.leeds.ac.uk/atomic	April 2004
2	Statistics Canada	http://estat.statcan.ca/cgi-win/CNSMCGI.EXE?ESTATFILE=EStat\English\E-Main.htm	April 2004
3	The American Cancer Atlas	http://www3.cancer.gov/atlasplus/index.html	April 2004
4	Nevada Ecosystem Project	http://www.crseo.ucsb.edu/biogeog/snep.html	May 2002
5	United States Census	http://www.census.gov/geo/www/maps/CP_OnLineMapping.htm	April 2004
6	CIET	http://www.ciet.org/www/image/maps/_maps-countrytheme.html	April 2003
7	Arizona State University	http://www.bgsu.edu/colleges/library/maps/maps.html	May 2002
8	The City of San Diego	http://cart.sandag.cog.ca.us/demog/default.htm	April 2004
9	NBCi	http://home.nbc.com/search/map	
10	Microsoft Terraserver	http://terraserver.homeadvisor.msn.com/default	April 2004
11	Ecotourism	http://www.gisca.adelaide.edu.au/cgi-bin/eco/ecogis (old)	May 2002
12	California Resource Evaluation System	http://ceres.ca.gov/geo_area/index.html	April 2004
13	Friends of the Earth	http://www.foe.co.uk/campaigns/industry_and_pollution/factorywatch/Information	May 2002
14	Information Center for the Environment	http://icemaps.des.ucdavis.edu/icemaps2/ICEMapInit.html	April 2004
15	Environmental Protection Agency	http://www.epa.gov/ceisweb1/ceishome/atlas/learngeog/interactivewebmapping.html	April 2004
16	National Geographic	http://plasma.nationalgeographic.com/mapmachine/	April 2004
17	The city of Sacramento	http://maps.cityofsacramento.org/default.htm	April 2004
18	Nursing Home Information	http://www.nursinghomeinfo.com/search.html	April 2004
19	The World Health Organization	http://www.who.int/csr/mapping/mappinginwho/en/	May 2002
20	The Artic Mapping System	http://maps.grida.no/arctic/	April 2004
21	United Nations Environmental Program	http://www.unep-wcmc.org/index.html?http://www.wcmc.org.uk/CITES/redirect.htm~main	April 2004
22	Austrian Federal Environmental Agency	http://www.ubavie.gv.at/	May 2002
23	Children's Report Card	http://www.mnplan.state.mn.us/cgi-bin/datanetweb/chi_dpm/	April 2004
24	Humboldt Bay	http://humboldt.cnr.humboldt.edu/gis/gis.html	April 2004
25	USA Department of Environmental, Food and Rural Affairs	http://www.defra.gov.uk/wildlife-countryside/ewd/rrrpac/lreview/07.htm	May 2002
26	Health Canada—Disease Surveillance On-line	http://www.hc-sc.gc.ca/pphb-dgsp/dsol-smed/index.html	April 2004
27	Health Canada—FLU watch	http://www.hc-sc.gc.ca/pphb-dgsp/fluwatch/index.html	April 2004
28	Environment Canada—Species at Risk	http://www.hc-sc.gc.ca/pphb-dgsp/dsol-smed/	April 2004
29	Census Mapping ESRI	http://maps.esri.com/ESRI/mapobjects/tmap/tmap.htm	April 2004
30	US Center for disease control	http://maps.esri.com/scripts/esrimap.dll?name=mmwr&cmd=start	April 2004

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