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Creation of environmental health information system for public health service: A pilot study

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Abstract Despite more than a decade of research on medical information systems, deficiencies exist in our capability of establishing an effective environmental health information infrastructure. In this research, we present a pilot study on creating a feasible environmental health information infrastructure. The newly-developed environmental health information system is a web-based platform that integrates databases, decision-making tools, geographic information systems for supporting public health service and policy making. The study, which is a part of a comprehensive effort known as Environmental Public Health Tracking proposed by the Center for Disease Control and Prevention, opens the door for future research on a large scale nation-wide healthcare information infrastructure.

Keywords Environmental health · Internet medicine · Information network · Public health · Decision-making · Healthcare service · Geographic information systems · Integrated information system

1 Introduction

The dawn of the 21st Century sparks our ambition of using information technology to develop health service infrastructures so as to improve accessibility to healthcare data and enhance heath service delivery quality. To promote the development of healthcare information infrastructures, a number of Acts concerning information technology application have underscored the importance of technology implementation in the healthcare sector. The High Performance Computing Act in 1991, the Next Generation Internet Act in 1998, and the Networking and Information Technology Research and Development Act in 2000 have all addressed the needs of applying information technology to healthcare service. In June 2000, the National Committee on Vital and Health Statistics released a report on creating the national health information infrastructure (National Committee on Vital and Health Statistics 2000). The report proclaims that we are in the midst of a dynamic technological era where dramatic transformations in information and communication technologies offer us unprecedented opportunities to create a healthcare information infrastructure.

Today, environmental-related chronic disease and outbreaks of epidemiology are some of the most noticeable healthcare issues. The American people feel strongly that

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the environment plays a role in their health. A poll taken in 1999 by the Pew Charitable Trusts reported that 87% of Americans believed that environmental factors such as toxic chemicals, polluted air and water cause increased rates of diseases and health problems (McGeehin et al. 2004; Pew Charitable Trusts 1999).

As environmental pollution gets more serious, diseases with proven association with environmental exposure such as cancer, birth defects, asthma, bird flu, and respiratory problems add health burden to the US population and health service providers. For example, in a 1996 Harvard Report on Cancer Prevention, researchers pointed out that 9% of cancer death are environmentally related. Though environmental factors are known to be important to human health, there is no comprehensive information system available that can be employed to trace where, when, and how environmental pollution is affecting human health. However, serious facts exist. For example, a scenario of potential bird flu explosion could paralyze the entire nation's healthcare delivery system and medical supply chain. The US Government is concerned that the ongoing outbreaks of health epidemiology could significantly impact the people's health and the nation's economy.

Currently, environmental hazard exposure and disease information is stored in many disconnected locations using different data formats and systems. This status hinders health professionals from providing the best and timely health service to the public and puts off policy makers to develop relevant healthcare policies in time. The infrastructure gap between the existing environmental public health information systems and the efforts of collecting data on diseases, human exposures, and environmental hazards is obvious.

This paper was motivated by the need to address the gap in the application of information technology to environmental health services. This research presents an initial effort to propose an architectural framework of environmental health information tracking systems that has the potential to provide healthcare providers and the general public with data, information, and decision tools for healthcare decision-making. The proposed integrative framework and system is illustrated with a prototype through a pilot project. The proposed system, which is a part of the Environmental Health Information System (EHIS), is a set of integrated data, decision support tools, geographic information systems (GIS) technologies, and applications that support all facets of environmental public health service.

In this paper, we (1) propose an architectural framework that integrates environmental health information systems within and between organizations; (2) develop a deliverable environmental public health information system, and (3) present health service decision-making options through the prototype environmental public health information system described in (2).

This study makes a couple of contributions that include (1) developing an integrated public health information tracking system to replace the existing fragmented and disconnected information systems at individual organizational levels; and (2) demonstrating the use of the environmental public health tracking system to assist health service professionals in making decisions.

This paper is structured as follows. "Section 2" provides an overview of the need for an integrated environmental public health tracking system, and the challenges and benefits of creating the system. "Section 3" contains a presentation of the integrative architecture considered in the system development and provides the motivation behind the choices of the employed technologies. "Section 4" provides an application example. "Section 5" discusses the value and managerial implications of the system for environmental healthcare administration. Conclusions are given in "Section 6".

2 Background

2.1 The need of environmental public health tracking system

Environmental health data have been collected at a national level by government agencies for several decades. One of the earliest public health records was established in 1741 in the US, when tavern-keepers in Rhode Island were required by statute to report to local authorities any customers known to harbor contagious disease (Gostin et al. 1996). Starting from 1850, nationwide data on mortality was collected. At the beginning of the 20th Century, all state and city governments were required to report communicable disease such as smallpox and tuberculosis to the federal agency. In the recent public health history, the collection of public health data has benefited mankind to prevent the outbreak of serious epidemics and to design effective intervention strategies. For example, the detection of the acquired immunodeficiency syndrome (AIDS) was credited to the reporting of contagious disease. In the early 1980s, shortly after the report of a cluster of cases of unusual pneumonia and rare cancers among gay men, human immunodeficiency virus and AIDS were identified (Gostin et al. 1996). The world has, since then, invested enormous amount of resources to prevent and fight this so far uncurable disease.

Now, let us consider air pollution for a moment. The top five health concerns related to air quality in the US are cancer, exposure to chemicals, heart problems, asthma, and getting sick. Facing the challenge of environmental health threat, the Centers for Disease Control and Prevention announced an initiative to develop a national environmental public health tracking network that integrates existing environmental and chronic disease data. In September 2000, after 18 months of review, the Pew Environmental Health Commission released a report on the state of environmental public health in the United States (Environmental Health Tracking Project Team 2000; McGeehin et al. 2004). The commission has noted that at the present there is no integrated environmental public health system that links information on environmentally related diseases, human exposures, and environmental hazards. Establishing a national environmental public health tracking network to link fragmented data or neglected information is urgent to respond adequately to environmental threats (Urtubey et al. 2004).

2.2 The operational goal of environmental public health tracking system

The primary operational goal of creating an environmental public health tracking network is to identify environmental hazards, prevent and reduce human exposures, minimize population risk for developing diseases, and prepare for potential outbreak of bio-terrorism. The Centers of Disease Control and Prevention envisioned that the environmental public health tracking network will be an internet-based network that will provide access to environmental and health data that are collected by a wide variety of agencies. It is a national network that comprises of state-level public health information systems. The environmental public health tracking network will make health data and operational tools available to various public health service agencies, and establish a common data vocabulary and standards for public health service organizations to exchange data and share relevant information. Collaboration at local, state, regional, and national levels will be improved as public health service agencies apply the same data and communication standards (CDC 2007).

2.3 The challenge

Developing a public health information infrastructure has recently attracted a lot of attention. As early as 1996, US health professionals reviewed the law and privacy related to public health information infrastructure development (Gostin et al. 1996). Yet, the researchers and practitioners are still faced with a number of challenges before an effective environmental health information system can be fully implemented. Data standards, public health vocabulary, information system compatibility, and well-trained staff are a few significant issues (CDC 2007; Li and Benton 2006; McGeehin et al. 2004). When information systems do exist at individual organizations, data formats and standards vary. These limitations present noticeable challenges to creating a national integrated internet-based information network. Center for Disease Control and Prevention (CDC) and its local and state partners are currently identifying data needs of their constituents and evaluating mechanisms and costs for improving data and filling the gap of an integrated tracking system (CDC 2007; Kass et al. 2004; McGeehin et al. 2004; Ritz et al. 2005).

Environment health data collected at different levels using different data formats seriously affect the accuracy of health data. In a mini-monograph, McGeehin et al. (2004) presents results of some innovative methods for acquiring and integrating public health data through a non-traditional approach. For example, Knorr et al. (2004) contacted school nurses in Massachusetts public and private schools directly to get a more reliable estimate of asthma prevalence of K-8 students at the local level. The Massachusetts Department of Public Health provided a standardized form and successfully collected asthma surveillance data from 70% of targeted schools serving more than 311,000 students through its school-based pediatric asthma surveillance system. Further consideration, following the data collection, is to link health data with environmental databases and geo-code school addresses to connect school asthma data to existing ambient air quality data.

Data system compatibility is an issue that is addressed at both the federal and state levels. Various data vocabularies and data systems speak different languages and can't be integrated to a national public health information network. The work of Hanrahan et al. (2004) on development of Wisconsin's childhood cancer surveillance project is an initiative for overcoming technology incompatibility in designing an integrated data repository. It is an information technology platform that includes a number of functions, such as automated exchange of cancer case data between public health-based and hospital-based cancer registrars, web-based supplemental data entry, automated data analysis, and public health information dissemination and alerting.

The lack of a well-trained workforce to design and operate an integrated environmental public health network is a considerable challenge. The Institute of Medicine committee found that public health infrastructure and workforce development are two important factors to ensure provision of essential public health services (Institute of Medicine 2003). This finding echoes the results of an empirical study on technology implementation and staff skill requirements in US hospitals by Li and Benton (2006). They indicate that the implementation of new technology often activates changes in organizational structure, business processes, and employee skill requirements. As such, a well-trained, highly motivated, and dedicated workforce is essential for ensuring the quality of health service.

2.4 Avenue for developing integrated healthcare information system

Since 2000, there are increasing efforts and resources devoted to developing internet-based environmental health tracking systems. CDC has collaborated with states to build Environmental Public Health Tracking (EPHT) system at the state level first. This initiation aims at facilitating the electronic transfer of appropriate information from local information system to public health agencies, detecting epidemic outbreaks, and enhancing both timeliness and quality of health information provided. The information from the tracking network can help find the cause of health problems and develop public health decision making strategies.

Currently, comprehensive environmental public health information systems do not exist at the local, state, or national levels to track many of the exposures and health effects that may be associated with environmental hazards (CDC 2007). In the last decade, many information technology breakthrough efforts have laid the foundation for a health information infrastructure. For example, information systems for processing financial information have progressed from stand-alone system to world-wide networked systems. The promise of advanced telecommunications technology has provided a major premise for the creation of an environmental public health information network.

Since 1980, there has been major shift in the impact of technology on the health care system world-wide. Perhaps the most significant impact is that of information technology as the driver for medical consumerism (Li and Benton 2006; Xu and Li 1992). Medical informatics has evolved from stand alone databases, to integrated information system within the organization, and to integrated networked health service information systems.

3 Architectural framework of environmental health information system

3.1 Development of internet-based environment health information system

In this section we present the development of an integrated information system for environmental health tracking purpose. To a certain extent, quality environmental health tracking systems for healthcare purpose are almost non-existing. This project is a pilot study, which is at its initial stage. The system is a robust web-based portal/platform for environmental health tracking in Virginia. The system provides a variety of functions including: web-based data entry, secure and automated exchange of data between agencies, data visualization, automated data analysis and decision support, environmental health information dissemination, and environmental health information infrastructure development. For the application purpose, data can be sent electronically to the system, be analyzed, explored and mined using decision science techniques for environmental healthcare tasks. In addition, the system is able to provide information useful to emerging infectious disease surveillance and prevent bioterrorism. The proposed integrated Internet-based EHIS can, thus, serve as the basis for building a more robust, comprehensive information infrastructure for more efficient healthcare delivery. The following provides the description of the various aspects of EHIS.

3.2 System overview

The system developed in this research is a Browser-Server System, which consists of three major components: user, Web Browser, and EHIS server as shown in Fig. 1. The web-based EHIS provides a vast repository of information and can be used for a variety of purposes such as sharing environmentally related data, searching for information, providing healthcare service and support, and collaborative work among various healthcare providers and stakeholders.

The flow of the EHIS system is illustrated in Fig. 2. Http Daemon is always at running status. The request for environmental health information is initiated from the end user, transferred to Http Daemon, and then transmitted to common gateway interface (CGI) which is called by http Daemon. The CGI is an independent program which can access other system's interface, such as database, statistical analysis system (SAS), or GIS. The detailed processing flow is described as follows.

1. The system starts with a health service agent's request for data. When the health service agent requests EHIS data through the web page, the request is sent through the browser;
2. Http Daemon receives the request and transmits the request to CGI.

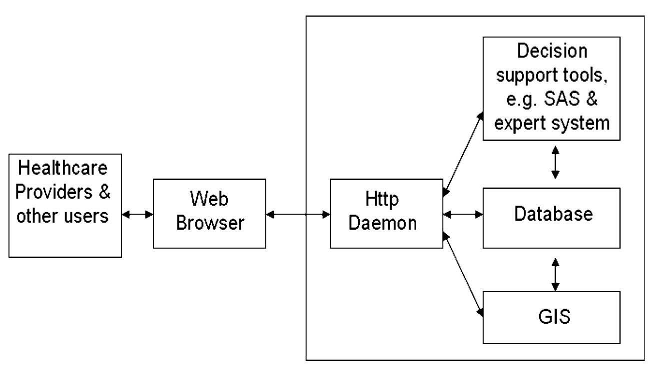

Fig. 1 The EHIS information system

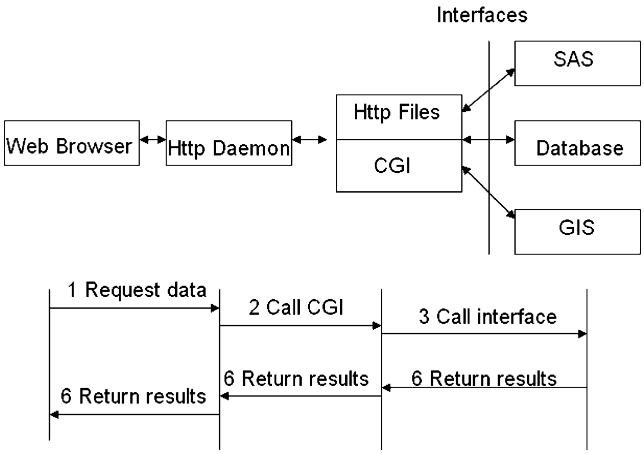

Fig. 2 Information flows and services

3. CGI then calls Interface. Based on the user's request, specific application will be activated. For example, if a user is interested in conducting a frequency analysis of percentage of adults with asthma in 2005, CGI will call the interface provided by SAS, and prepare the proper parameter for SAS;
4. Based on the parameter, SAS provides statistics on asthma and returns the result to CGI;
5. CGI returns the result to Http Daemon; and
6. Http Daemon returns asthma statistics to the browser. Finally, the health service agent receives the result on asthma from the browser.

3.3 EHIS server components

The EHIS server presented in Fig. 1 can be one or several machines. The system includes Http Daemon, database, decision support models, and GIS. Special features for information security have been considered for the servers such as firewalls, virus protection, and intrusion detection. Appropriate administrative policies have also been developed. The selection of software tools depends not only on the particular activities in the environmental health domain, but also on the potential contribution to data integration and information sharing among all partners of the system.

3.3.1 Http Daemon

Http Daemon is a program that is designed to wait for Http requests and handles requests when they arrive. When the browser user enters file requests by either "opening" a Web file (typing in a Uniform Resource Locator (URL)) or clicking on a hypertext link, the browser builds an Http request and sends it to the Internet Protocol address indicated by the URL. The Http Daemon in the destination server machine receives the request and sends back the requested file or files associated with the request. A daemon is a program that runs continuously and exists for the purpose of handling periodic service requests that a computer system expects to receive. The daemon program forwards the requests to other programs (or processes) as appropriate.

3.3.2 Database

Integrated databases are becoming a commonplace as healthcare organizations engage in internet medicine and virtual services that require the integration of geographically distributed health data. Such data can further be mined to provide decision aids, to support environmental health tracking, and to measure health program effectiveness. The ability to meaningfully integrate existing, yet disconnected, data sources is the cornerstone of the proposed prototype system. Such integration requires standard methods for efficiently and effectively linking records from one source to another. This task is full of challenges. Maintaining data accuracy during data integration, securing confidential health information, applying appropriate analytic techniques, selecting control variables, and managing temporal and spatial requirements of the data are a few examples. For aggregated data, the resolution at which the data are collected, linked, and stored need to be considered upfront (Johansson et al. 2003). Additionally, data quality and timeliness, integration of health and environmental data, data completeness, and the standards for the EHIS system are issues need to be taken into account in advance.

A data network established in this system links environmental data and health data from various sources, including statewide health and environmental monitoring information, published national environmental data, and census data. As the environmental health data are linked and integrated, the relationship between exposure and disease can be analyzed and studied using mathematical models. There are three types of input: data, metadata, and maps. The metadata provides a description of the parameters used in the environmental health model. The maps provide input information on air, ecological conditions, etc.

3.3.3 Geographic information systems

GIS software is unique in its ability to capture, store, and manage spatial data (Tang et al. 2001). In EHIS, GIS incorporates digital images with the database system. It is useful in our applications dealing with the geographical data such as environmental monitoring, public health surveillance, and epidemiological investigation data. The GIS allows healthcare providers and other users to formulate domain-related queries based on geographical objects such as states, cities, counties, etc., thus both geographical/spatial information and the factual information from databases can be analyzed and presented. For example, GIS can be used to investigate respiratory health effects of airborne emissions and assess the prevalence of asthma. In a typical study using GIS, data for both disease patients and background geography/population are imported into the GIS for analysis.

The prototype system has demonstrated the value of using GIS for analyzing environmental health data. Through a combination of the database, spatial analysis, and graphical displays, GIS provides the capability of relating and analyzing datasets from different sources. Equipped with EHIS, users can define their own geographical areas of interest to identify geographically related environmental health effects, and environmental information such as the location of air emissions. The prototype system employs one of the most appealing features of GIS to present analytical results in map format. Additionally, GIS tools are applied to assess environmental exposure risks.

3.3.4 Decision support tools

One of the major goals of the EHIS system is to create a system that can assess environmental heath effects so as to guide the formulation of effective healthcare strategies. To accomplish this, mathematical models have been incorporated to EHIS, along with the Graphical User Interfaces, database, and GIS for temporal and spatial data processing and visualization (Rao and Turoff 2000).

Statistical techniques, such as frequency distribution, regression, chi-square analysis, and multivariate analysis, are commonly used to analyze environmental and health data. The EHIS system is equipped with decision models to analyze trends, detect patterns and relationships among hazard, exposure and health effects in populations. For example, methods for trend analysis and aberration detection are enumerated and reviewed for appropriateness in analyzing asthma and air quality data sets.

Decision support models support healthcare decisions at different levels are incorporated. For the executive level decision-making, selected decision support tools are built-in in the system. These tools can help to decompose the complexity of the problem into manageable steps and generate decision support information for public health policy formulation. Tools for the operational level decision-making are also included. For example, expert system component included in the EHIS system is able to analyze an individual's environmental health-related risk factor profile to provide personalized wellness and clinical preventive care recommendations.

3.4 Data driven graphics-a data presentation approach

Both GIS results and decision support models can be presented using graphical approach. As such, effectively displaying the statistic reports and tables in graphical format on the web page becomes an important design issue. Two alternatives of graphic presentation were considered during the design process. One is to draw graph on the user's machine. The other is to embed a mechanism in the system which can be used to generate graphs. The first option requires the user to install some software to support this function, which requires extra investment in the software on the user's side. The second option is more convenient to the user than the first one. Consequently, the second option is selected. A technique called "data driven graph generating process" is then developed. The basic ideal of the technique is presented in Fig. 3.

Six steps are presented in Fig. 3 to illustrate the data driven graph generating process.

1. The user request for data graphs. The request is passed through the interface of the Process Daemon;
2. The Process Daemon selects a relative process (such as Drawing Process) to service;
3. The Drawing Process accesses the database to retrieve relevant data;
4. The Drawing Process draws the graph using a graph engine;
5. After getting the Image/Graph file from the Drawing Process, the Drawing Process returns the file to the Process Daemon;
6. If the user has other types of request, such as user direct request drawing service, the Drawing Process can be initiated.

To facilitate graphical presentations, a graph engine/ library is developed. The graph engine used in the prototype system is JFreeChart which is retrieved from a free Java chart library. JFreeChart can be applied to both Windows and Unix environment. Additionally, JFreeChart supports many output formats, such as Swing components, image files (including portable network graphics and joint photographic experts group (JPEG)), and vector graphics file formats (including portable document format, encapsu-

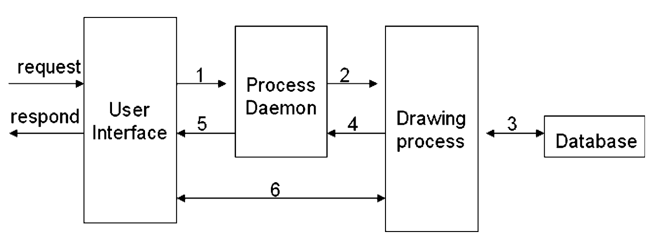

Fig. 3 Data driven graph generating process

lated postscript and scalable vector graphics). Though the code is free, a considerable amount of time was spent to tailor the code to the EHIS system.

The process of JfreeChart is presented in Fig. 4. First, a ChartRenderingInfo Object is created and passed as a parameter to the ChartUtilities.writeChartAsJPEG. The user will get an Image or Graph file and a ChartRenderingInfo that is filled with some type of data. However, the map data will not be generated directly; ChartUtilities.WriteImageMap method needs to be called to read ChartRenderingInfo. A sample code of image-writing is presented in Fig. 5.

JFreeChart separates the data from its presentation layers. The procedure of using graphs and charts function can be summarized as follows:

1. Generate or load the data;
2. Create the appropriate type of presentation style such as pie chart, Gantt chart, line graph, stacked bars, etc.;
3. Customize the data presentation;
4. Finally, release the graphic presentation to a Swing application, and then integrate the graph in a web application to serve the graph, or to save the graph to a file.

All data that is presented by JFreeChart must implement the org.jfree.data.Dataset interface. Specifically, they must implement a sub-interface specific to a particular graph type. For example, data that will be read by a pie chart need to implement the org.jfree.data.PieDataset interface. The default interfaces exist for most of dataset interfaces and org.jfree.data.general.DefaultPieDataset will be used.

```
PrintWriter w = null;
FileOutputStream fos_jpg = null;
FileOutputStream fos_cri = null;
try{
        //different chart will use different class, here using Pie chart
        PiePlot plot = (PiePlot) chart.getPlot();
        plot.setURLGenerator(new StandardPieURLGenerator(url));
        //setting ToolTips
    plot.setToolTipGenerator(new StandardPieToolTipGenerator());
        fos_jpg = new FileOutputStream("d:\\fruit.jpg");
        ChartUtilities.writeChartAsJPEG(
                fos_jpg,
                100,
                chart,
                400,
                300,
                info);
        fos_cri = new FileOutputStream(__d:\\fruit.map__);
        w = new PrintWriter(fos_cri);
        ChartUtilities.writeImageMap(w, __mapname__, info);
        w.flush();
}finally{
        try{
                w.close();
        }catch(Exception e){}
        try{
                fos_cri.close();
        }catch(Exception e){}
        try{
                fos_jpg.close();
        }catch(Exception e){}
}
```

Fig. 5 Sample code of image-writing

4 An application example

The EHIS system developed in this research has been tested using information from H city in Virginia. H city is home to numerous industry facilities, which releases a certain amount of hazardous air pollutant. Residents bordering these facilities are concerned about the impact of air pollution on their health. One of the appealing approaches to address such concerns is through a focused intervention with strong environmental heath data support.

The Browser-Server System was developed. The web-based environmental health information system (shown in Fig. 6) connects data and information from stakeholders that include the general public, healthcare providers, government agencies, policy makers. It also provides a repository of information that can be used for a variety of purposes such as entering data, sharing environmental related information, searching for information, and providing healthcare decision support.

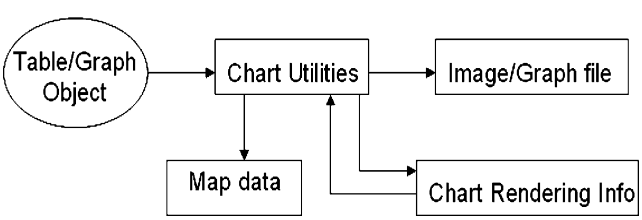

Fig. 4 Process of JfreeChart

A database was then created that includes a number of previously disconnected data sets that we obtained from various partners. The database we established integrates four quarters' information of asthma cases, 2003 population for each zip code, environmental data set containing TRI sites, air emission by zip code, and demographic data containing population sizes by race.

After we established the database, GIS system was employed to project asthma rate by zip code, air emission, etc. to provide a visual presentation. An example of GIS graph is presented in Fig. 7.

Then, decision support tools are employed to generate insights for intervention strategy. SAS software was the vehicle used for data manipulation and analysis. A number

Fig. 6 Web browser

of statistical models were used to analyze the data retrieved from the integrated database.

The formula used for computing asthma rates for these zip codes is as follows:

$$\text{Asthma Rate} = \frac{\#\text{of asthma cases}}{\text{pop 2003}}.$$

To further determine the differences in asthma rates for different age groups, three age groups are established: Young (age less than or equal to 24), Midage (age between 25 and 64), and Old (age greater than or equal to 65). The asthma rate for each of these groups is calculated in the same way as above, except for some adjustments. For example, for the "Old" group the asthma rate is:

$$\text{Asthma Rate}(\text{for}\,''\text{Old}'') = \frac{\#\,\text{of asthma cases}(\text{for}\,''\text{Old}'')}{(\%\,\text{of}\,''\text{Old}''\text{people in the zip code}) \times (\text{pop 2003})}$$

The rate is highest for age group "Old" and other two rates are comparable.

After that, the regression model was established to analyze the relationship between asthma rate and emission:

$$\text{Asthma\_rate} = \beta_0 + \beta_1 \text{age\_group} + \beta_2 \text{emission}$$

The results indicate that there is a positive relationship between asthma rate and emission, but the average rate is different for different age group. The graphical solution (in Fig. 8) illustrates the association between the age-group and air emission, and the number of asthma case.

The pilot prototype system allows us to access ongoing and existing health data, and monitor health data regarding human exposure and environmental hazards. By accessing and analyzing such valuable data, appropriate healthcare decisions or policy can be formulated based on the relationship between environmental factors and human health, and effective prevention measures can be taken to control the breakout of serious epidemiology.

5 Discussion and future research

The web-based environmental health information system helps facilitate environmental healthcare services and generates values that support public health decision-making. A few benefits can be summarized as follows:

1. Environmental health data accessibility and information exchange. The significance of the integrated information system is to provide environmental health data and information through a network of integrated environ-

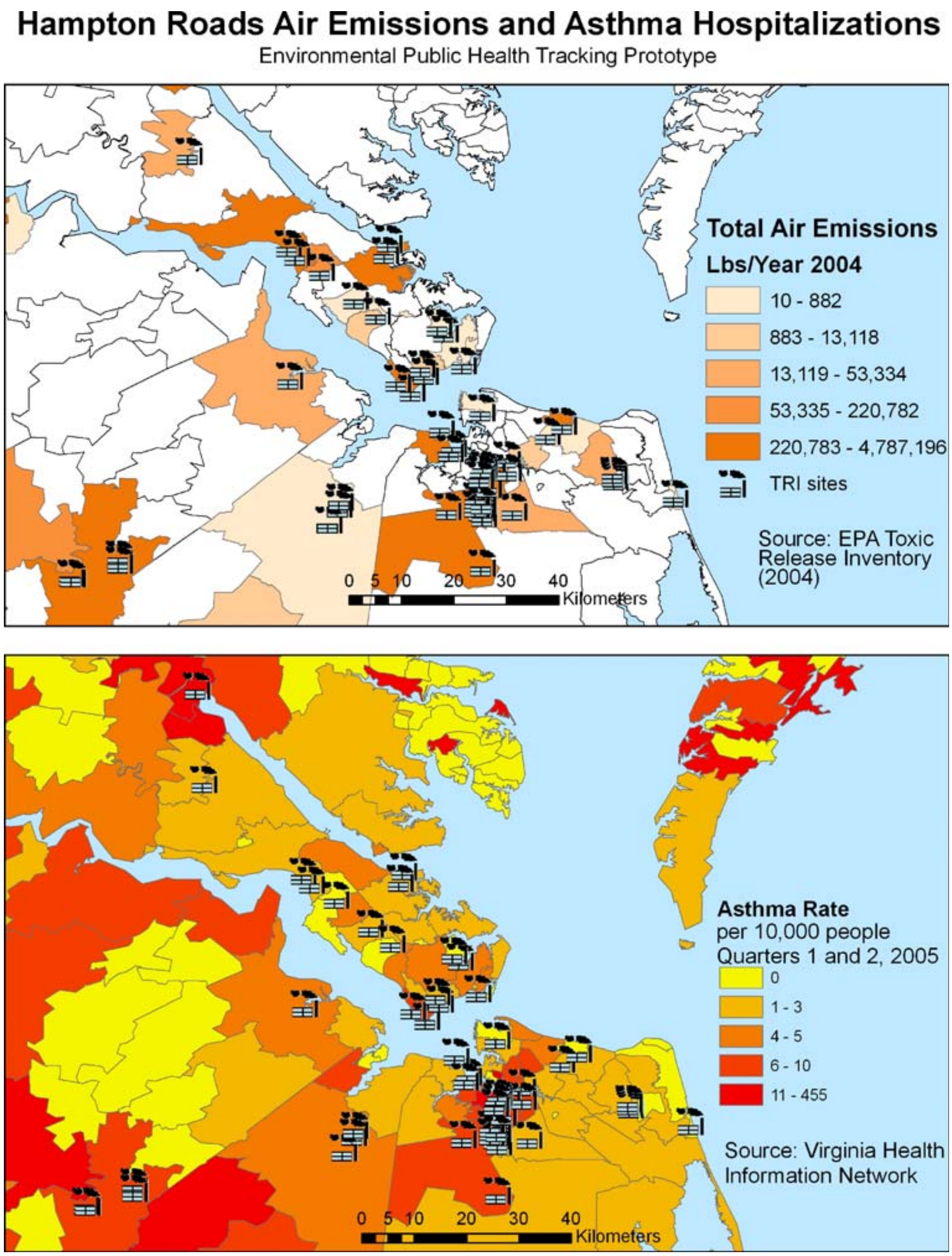

Fig. 7 GIS mapping

mental monitoring and public health information systems, so that all partners can be equipped with necessary information to take action and prevent environmentally related health effects. The EHIS system provides a vast repository of information and facilitates extensive search and retrieval of environmental heath information. Through electronically sharing environmental health data, health service agencies are able to obtain both temporal and special environmental health information in a timely manner. The web-based user interface provides convenient, reliable and secure data across geographically dispersed locations as well as various time zones.

2. Information visualization. The graphic engine of the EHIS system translates specific numeric results into charts, maps, and other graphical presentation. The implementation results show that information visualization is an effective approach to assist users in gaining quick insights into the quantitative data (Li et al. 2001).
3. Health service in information age. Environmental health care administrators comment that the process of creating the system gave them new insights into the way environmental healthcare operates in the information age. With the experience of using the pilot prototype system, administrators are motivated to develop an integrated information technology infra-

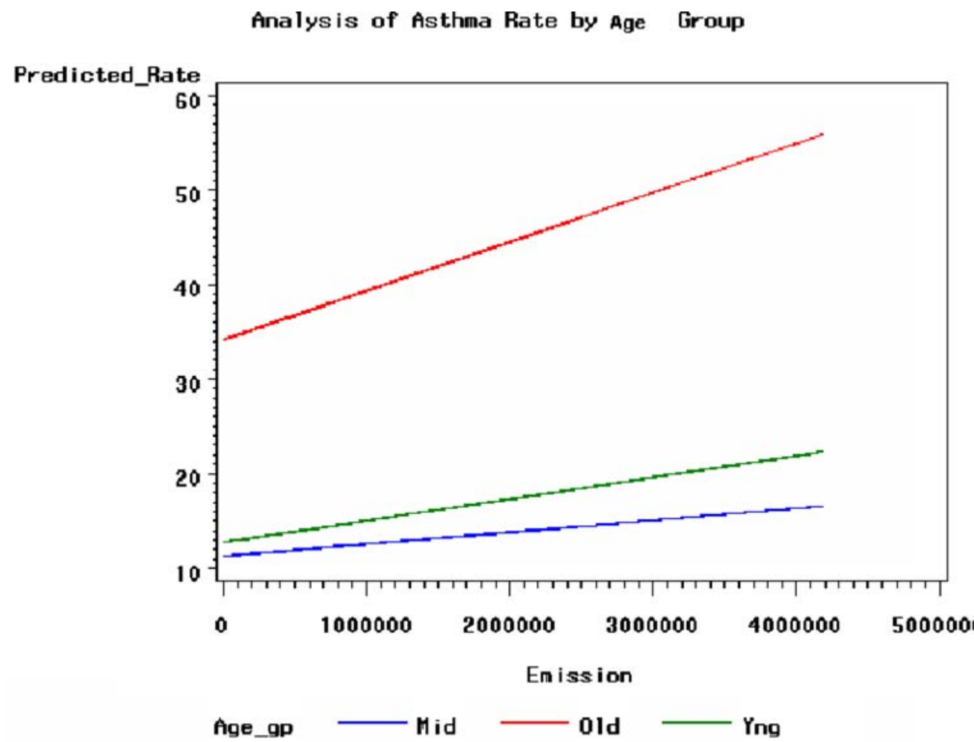

Fig. 8 Asthma rates by air emission and age group

structure that integrates a broad array of application software in the environmental health area.

We have demonstrated an integrated information system that integrates databases, analytical models, GIS, and web-based technology (Warfield 2007; Xu et al. 2001, Xu 2007). One of the benefits of the prototype lies in its ability to guide future research. The results of the prototype system holds promise that we will be able to integrate more features into the environmental health tracking system. A few suggestions for future research are proposed below.

1. During the system development, we encountered a number of technical challenges. Lack of standardized data format and vocabulary create a real problem in data integration. Future research may consider how to standardize and transform a broader range of data that are stored in different formats.
2. System connection is another challenge. Effectively connecting various decision support models to provide visualized results requires more research and advanced technology.
3. The tool set for health service decision support can be further expanded. For example, tools for linking data geographically, tools for descriptive and small-area analyses, and tools for data dissemination.
4. How to best utilizing environmental health information infrastructure for public health planning and resource allocation is another new topic. A couple of examples of public health planning and resource allocation issues include how to transform health data collected to meaningful information on migration and socio-demographic factors, how to interpret spatial and temporal trends, and how to relate hazards exposure patterns to chronic diseases intervention strategies.
5. With the new environmental information system, healthcare personnel training becomes an immediate issue that need to be tackled.

6 Conclusion

Despite more than a decade of research on medical information systems, deficiencies exist in our capability of establishing an effective environmental health information infrastructure. Although individual systems have long been developed, the integrative environmental health information infrastructure still remains as a hope (Hanrahan et al. 2004; Knorr et al. 2004; Li and Benton 2006; Zhang et al. 2007). In this research, we have presented a pilot study on creating a feasible environmental health information infrastructure. The study which is a part of a comprehensive effort, known as EPHT proposed by CDC, opens the door for future research on a large scale nation-wide healthcare information infrastructure. The contributions of this study include enhancing the feasibility of creating a national healthcare information infrastructure, and developing an integrative environmental healthcare tracking framework and a prototype system based on the framework. The most important contribution is that the EHIS system sets up a baseline for future research on a better environmental healthcare information infrastructure.

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