GIS for epidemiological studies

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SUMMARY

In the year 2001 Italian National Research Council (CNR) performed "Ospedaletto project" with the aim to assess the environmental and people health status in south-east area of Pisa (Tuscany, Italy), near a waste incinerator.

An epidemiological survey was performed, asking a general sample of people (1408 subjects) for respiratory symptoms and diseases.

We classified the subjects on the basis of the houses distance from the waste incinerator, but the health status resulted not certainly linked with the past activity of incinerator; so the subjects were classified again with the aim to analyse a possible joint between their health conditions and traffic pollution.

We obtained a new classification of the subjects on the basis of the houses distance from the streets. Buffers of 100 metres from the secondary roads and 75 and 150 metres from the main roads were considered. The statistical analyses suggest significant relations between living near main roads and the increase of respiratory diseases.

KEYWORDS: *GIS & Health, Epidemiology, Environmental monitoring.*

INTRODUCTION

The human body is exposed to a complex mixture of chemical, physical and biological substances present in life and work environment, indoor and outdoor, in drink and in food. Some people are exposed to particular substances because of their work and their life style (tobacco smoke), but the whole population is generally exposed to low levels of air pollution.

The weight of air pollution sources depends on environmental and geographical factors: winds, geographical characteristics of the area, ratio between produced and scattered pollutants, seasons, urban concentration, industrial density and air pollution sources' density are the most important factors.

Our focus is air pollution originated by vehicular traffic. Recent international studies indicate that traffic produces important effects on human health: in fact urban air pollution has been strongly associated with cardiovascular and pulmonary disease and mortality, thus it is an important environmental risk factor (Pope, 2002; Brunekreef, 1997; Biggeri, 2001).

The aim of this work is to assess the effects of environmental factors on human health trough the use of GIS to model data collected during an epidemiological survey.

GIS AND EPIDEMIOLOGY

The GIS technology is recently considered as an important and new component in many epidemiological and health projects. Epidemiological investigations are designed to find out whether or not a statistically significant adverse health outcome is observed in an exposed group. Very large sample size is necessary to detect small increase in disease with exposure. Characterizing exposure involves: locating sources of potential toxicants, analyzing the transport and ultimate fate of toxicants

released from these sources, collecting and analyzing samples that offer a measure of the environmental quality at various locations from air, water and soil, describing the locations and demographic characteristics of exposed and susceptible populations, and modelling the conditions of human exposure. GIS can be useful in many of these analyses (Cromley and McLafferty, 2002).
The relation between epidemiology, statistics and Geographical Information System can improve the health research (Gatrell and Senior, 1999).
The GIS establishes spatial relations between a disease and other information (the distance of the possible pollution sources, the presence of cluster...), through the geocoding; other GIS tools important for epidemiology are the overlay process and the buffer calculation.

STUDY AREA

The study area is the south-east part of Pisa (Tuscany, Italy), around the Ospedaletto hamlet; in this area there is an urban waste incinerator, that during the study wasn’t operative for technical reason. In this area there is an industrial-craft area and an experimental setting up for special waste too.
This area is five kilometres distance from the centre of Pisa and it is crossed by main roads (Emilia road, Tosco-Romagnola road and Florence-Pisa-Leghorn freeway).

BACKGROUND

The study is based on a project worked in Ospedaletto area in 2001; the aim of the project was the assessment of the incinerator pollution’s effects on people living within a radius of four kilometres from the incinerator.
The study area was divided in homogeneous areas for exposure to air pollution; in particular the area was divided by concentric circles with rays from incinerator of 1400, 2700 and 4000 metres, respectively, in 3 circular rings (as illustrated by figure 1).
The results of the health study suggested relations between the exposure to the incinerator and the risk of respiratory symptoms and diseases in males only. However, in the environmental study, the results of the air quality monitoring, suggested that near the main roads there was a higher air pollution level than in the rural area; so we decided to investigate another air pollution source: vehicular traffic.

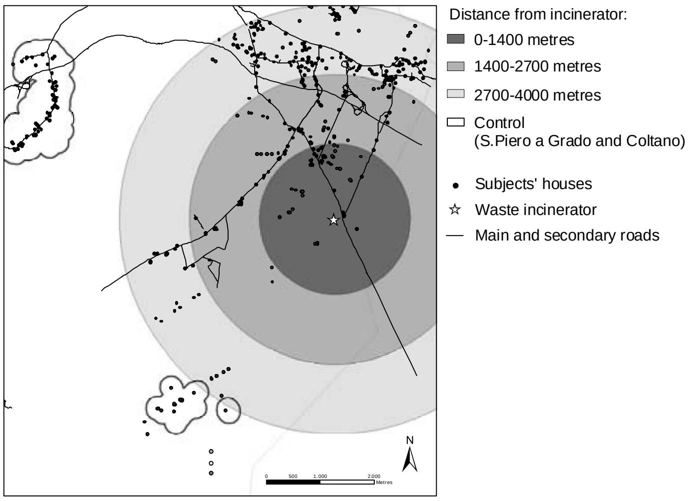

Figure 1: Zone classification based on the distance from incinerator

DATA ANALYSIS WITH GIS

In the current approach (traffic pollution) we used GIS as a technological instrument and as a decision support to scale the level of exposure to traffic exhaust of subjects, after a spatial explorative analysis of the area.

For the analysis of people we chose a model based on the home address of subjects selected for the investigation. In particular all the subjects are represented by a punctual mark on the map, that we obtained joining the geographical coordinates up to the street number (geocoding).

This operation has been possible because the Pisa Municipality runs an efficient geographical information system, with detailed cartography (scale 1:2000), and a valid street number mapping.

To classify the subjects we considered the locations of the houses, their positions with respect to the main roads, the dispersion models of linear pollution sources and the bibliography.

The dispersion models and the information about the traffic pollutants (NOx, CO, particulate, hydrocarbon and heavy metals) indicate that the major contrasts in pollution levels exist in proximity of roads, the levels being very high at the roadside and decreasing exponentially with distance from the curb side to reach a plateau by approximately 150 metres (Transport’s Department, Scotland and North Ireland, 1994).

About bibliography, a study about the relation between living near major roads and risk of wheeze in children shows that living within 90 metres of the streets increases the risk of disease in children; in this study children living within 150 metres of a main road were chosen, in fact at this distance the traffic pollutant’s concentration adds up at the environmental background level (Venn, 2001).

METHODS OF CLASSIFICATION

In order to obtain the classification of the subjects, first we divided the study area in areas supposed homogeneous for exposure to traffic air pollution.

According to bibliography we chose buffers of 100 metres for the secondary roads and buffers of 75 metres (a value near 90 m, that Venn indicate as the distance of main effects) and 150 metres (the value of the plateau in the dispersion model of air pollutants) for the main roads.

In particular the exposure areas are (as illustrated by figure 2):

High exposure: intersection between two or more main roads 0-75 m, intersection between main roads 0-75 m and main roads 75-150 m, intersection between secondary roads and main roads 0-75 m.

Medium exposure: 0-75 m main roads, intersection between two or more main roads 75-150 m, intersection between secondary roads and main roads 75-150 m, intersection between two or more secondary roads.

Low exposure: secondary roads and 75-150 m main roads.

Control: the other areas.

The classification of people was then obtained by a simple GIS operation, intersecting the layer of points, that represent people’s houses, with the classified areas.

The table below schematically describes the classification and shows the number of the subjects belonging to each class:

Class	Exposure	No subjects
1	High	131
2	Medium	365
3	Low	519
4	Control	393

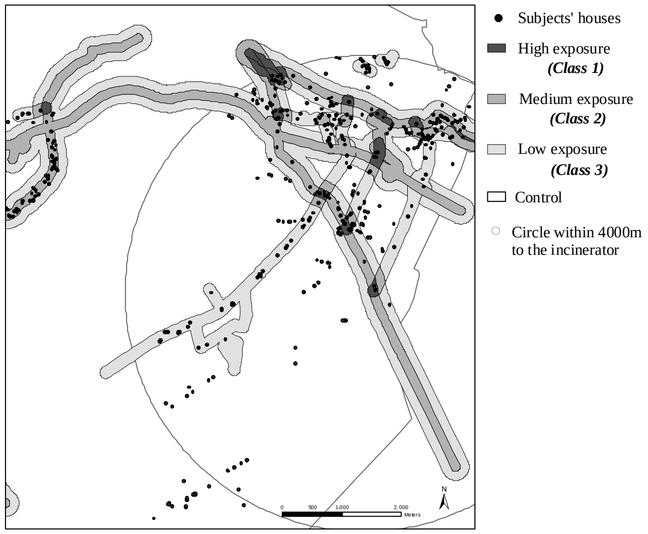

Figure 2: Zone classification based on the distance from the streets

Comparing our classification with the one referred to incinerator we discover that statistical powers of the two classification (fig.1 and fig.2) are similar (254, 288, 605 and 231 people in class 1 to 4 respectively in the incinerator approach).

STATISTICAL ANALYSIS

To overcome the limits of conventional epidemiological researches (analyses of mortality, of general diseases, of perinatal mortality, of the causes of the hospital admissions) in the Ospedaletto project, it was carried out an analytical epidemiological research, based on a self-administrated questionnaire, addressed to 1408 subjects living in Pisa Municipality.

The standardized questionnaire, based on the Italian National Research Council (CNR) model used in surveys carried out in 1980-2000, includes 10 chapters which allow to evaluate the environmental conditions, the subject’s health, confounder variables such as tobacco smoke, passive smoke exposure, occupational exposure, daily activity pattern, etc.

As explained, we used GIS facilities to obtain proper classification of subjects, after a spatial analysis of the study area. For statistical analysis, carried out on questionnaire’s data, we used then the Statistical Package for the Social Sciences (SPSS 10.0 of Windows), to assess if the initial hypothesis (null hypothesis) was supported from the reality. For bivariate analysis we used chi-square test to compare symptoms and diseases prevalence rates and analysis of variance to compare the mean values of continuous variables. In order to take into account the independent role of different risk factors, we used multiple logistic regression model.

RESULTS

About the relationship between gender and social status and respiratory illness, the multiple logistic regression model, that takes into account risk factors such as age, smoke habits, residential time, gender, education and job as social status proxy, suggested that in females there is a higher risk to have dyspnea (OR 2.09) and chest tightness (OR 1.68) but a lower risk to have asthma and emphysema than in males. About social status the analysis showed a relationship between respiratory symptoms/diseases and educational qualification only, there is no relationship with the type of work.

About the relationship between respiratory symptoms/diseases and exposure to traffic air pollution, the multiple logistic regression model suggested a relation between the risk of wheeze, attacks of shortness of breath with wheezing and the traffic exposure in females: in particular there is a main

risk in class 1 and 2 compared with the control class (respectively OR 2.84 and 2.01 for wheeze; OR 3.12 and 2.78 for attacks). In males there is a statistically significant association between chronic bronchitis and class 1 (OR 4.04) and between chest tightness and class 2 (OR 1.95) (table 2). These results suggest that traffic pollution exposure may represent a risk factor for respiratory health. Moreover, taking into account also the distance from the incinerator, we obtained an higher risk for wheeze (OR 3.57 in females) and attacks of shortness of breath with wheezing (OR 3.45 for class 1 and 2.99 for class 2 in females) in the subjects who live in high traffic area in respect to the logistic model not including the distance from incinerator. Moreover asthma in males (OR 2.14 for class 2) and chest tightness in females (OR 1.96 for class 2) have statistically significant values.
In males and females subjects highly exposed to traffic have higher risk to report the fume/gas exposure, heavy traffic exposure, high noise exposure, bad smell exposure and others decreasing with distance from the street.

The table 2 describes the significant associations with traffic exposure.

Gender	Effects	High exposure	Low exposure
F	Attacks with wheezing	Class 1	Class 4
F	Wheeze	Class 1	Class 4
M	Asthma	Class 2	Class 3
M	Chronic bronchitis	Class 1	Class 3
M-F	Chest tightness	Class 2	Class 3
M-F	Bad smell exposure	Class 1	Class 4
M-F	Fume/gas exposure	Class 1	Class 3 (2 in F)
M-F	Heavy traffic exposure	Class 1	Class 4
M-F	High noise exposure	Class 1	Class 3

Table 2: Significant associations between traffic exposure and respiratory symptoms, respiratory diseases, daily air pollution exposure.

CONCLUSIONS

Environmental epidemiology research attempts to associate adverse health outcomes with environmental exposure; in this study we chose the distance of the houses from the roads as proxy of exposure. This choice was possible thanks to GIS technology that allowed us to consider the location of the houses using geographical coordinates; moreover GIS allowed us to establish the different levels of air pollution exposure analyzing the presence of pollution sources and their distribution in the study area.
The results suggest a relationship between respiratory illness and the exposure to traffic air pollution, in particular females living near main roads present a risk of 257% for wheeze, of 245% for attacks of shortness of breath with wheezing and of 96% for chest tightness higher than females living in the control area; males who live near a major road are at risk for chest tightness (95%), chronic bronchitis (303%) and asthma (114%) than control males. The different results from the multiple logistic regression model carried out in males and females can suggest a different sensibility to air pollutants. This study confirms the results of other studies carried out on Pisa people (Viegi, 1999) and the results of other international researches (Ring, 1999; Nicolai, 2003; Garshick, 2003). The different associations with respiratory symptoms and diseases found in the two phases of the Ospedaletto study suggest that the two variables (traffic and waste incinerator) are independent risk factors for respiratory health. Thus, in atmospheric pollution study, we cannot analyse the punctual sources only, because this choice can be limitative and can underestimate the real exposure of the subjects.
This study is an example of the importance of an interdisciplinary approach in research and of the great role of GIS in public health (Venn, 2001; Nicolai, 2003; Hoek, 2002). As computer technology

continues to transform the ability of the users to analyze and map health data, new roles for GIS in public health may emerge.
In conclusion this study suggests that the epidemiological studies with the implementation of GIS technology are an important instrument to extend the environmental monitoring up to the inclusion of health monitoring.

BIBLIOGRAPHY

Biggeri A, Bellini P, Terracini B, Italian MISA Group. Meta-analysis of the Italian studies on short-term effects of air pollution. Epidemiol Prev. 2001;25(2 Suppl):1-71.

Brunekreef B, Janssen NA, de Hartog J, Harssema H, Knape M, van Vliet P. Air pollution from truck traffic and lung function in children living near motorways. Epidemiology, 1997;8(3):298-303.

Department of Transport, Scottish Office Industry Department, The Welsh Office, and Department of the Environment for Northern Ireland. Design Manual for Roads and Bridges 1994; Vol 11, Environmental Assessment (section 3). London: The Stationery Office.

Cromley E, McLafferty S. GIS and Public health. The Guilford Press, 2002.

Garshick E, Laden F, Hart JE, Caron A. Residence near a major road and respiratory symptoms in U.S. Veterans. Epidemiology. 2003 Nov; 14(6):728-36.

Gatrell AC and Senior ML, Health and healthcare applications, pp 925-38 in Longley, P.A., Maguire, D.J., Goodchild, M.F. and Rhind, D.W. (eds) Geographical Information Systems**,** John Wiley, Chichester, 1999.

Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. Lancet. 2002 Oct 19;360(9341):1203-9.

Nicolai T, Carr D, Weiland SK, Duhme H, Von Ehrenstein O, Wagner C, Von Mutius E. Urban traffic and pollutant exposure related to respiratory outcomes and atopy in a large sample of children. Eur Respir J. 2003 Jun; 21(6):956-63.

Pope CA 3rd, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA, 2002;287(9):1132-41.

Ring J, Kramer U, Schafer T, et al. Environmental risk factors for respiratory and skin atopy: results from epidemiological studies in former East and West Germany. Int Arch Allergy Immunol 1999;118:403-7

Venn AJ, Lewis S, Cooper M, Hubbard R, Britton J. Living Near a Main Road and the Risk of Wheezing Illness in Children. Division of Respiratory Medicine, University of Nottingham, Nottingham, United Kingdom. Am. J. Respir. Care Med., 2001;164(12):2177-2180.

Viegi G, Pedreschi M, Baldacci S, Chiaffi L, Pistelli F, Modena P, Vellutini M, Di Pede F, Carrozzi L. Prevalence rates of respiratory symptoms and diseases in general population samples of North and Central Italy. Int J Tuberc Lung Dis 1999; 3: 1034-1042.