Health and environment in São Paulo, Brazil: methods of data linkage and questions of policy

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Introduction

This article is based on a case study prepared at the request of the Health & Environment Analysis for Decision-making (HEADLAMP) project of the Office of Global and Integrated Environmental Health of the World Health Organization (WHO). The main purpose of the HEADLAMP initiative is to obtain information on which to base preventive action against environmental health problems. To achieve this aim, HEADLAMP promotes the development of methods to link environment and health data collected routinely within countries. The project intends to identify core environmental health indicators for use in environmental health management at local and national levels, and to encourage their use to direct policy.

Primarily, this article will address the development of data linkage methods, and will discuss briefly, based on existing experience with data linkage in São Paulo, the potential for routine environmental health monitoring and management in a major developing-country industrial centre.

At what could be called the macro level, we will look briefly, at an environmental hazard which may have broad health impacts for the population of the city: air pollution. At what could be called the micro level, we look at a complex of environmental hazards which affect the population of São Paulo differentially depending on household and neighbourhood circumstances. At this level, we review the use of routinely collected data on socio-environmental conditions (water consumption, population density, sanitation, income and education standards) and their linkage to health data.

For our analysis of data linkage methods, including issues of data quality and linkage potential, we draw heavily on recent research in São Paulo by Stephens et al. (1).\textsuperscript{d}

First, we shall give some background to the case study of São Paulo. Sources of population, health, socio-environmental and air pollution data are identified. Data are assessed on the basis of their availability (frequency of measurement, access and geographical reference) and their quality (completeness and accuracy). Current monitoring and linkage activities are presented, supplemented by ad hoc studies which have used the same type of data to demonstrate health links (2). Finally, the potential for Health and Environmental Data Linkage Analysis and Monitoring Projects in the São Paulo Metropolitan Area is discussed briefly.

Background information: São Paulo Metropolitan Area (SPMA)

The São Paulo Metropolitan Area (SPMA) is situated in southeastern Brazil and comprises 39 municipalities in a territory of 8 051 km\textsuperscript{2}. Map 1 shows maps of the SPMA and São Paulo City (SPC). Approximately 5 000 km\textsuperscript{2} of the SPMA is urbanized. São Paulo City, the main municipality of the metropolitan area and capital of the Brazilian state of the same name, occupies 1 577 km\textsuperscript{2}.

The SPMA contains 12\% of the Brazilian population. In 1991, 15 416 416 people lived in the SPMA, with 9 626 894 of them living in São Paulo City (SPC). According to this most recent census, the annual growth rate of the region has slowed from 4.5\% (3.7\% for SPC) between 1970-1980 to 1.9\% (1.2\% for SPC) from 1980-1990 (3).

Socio-economic environmental and health situation

The SPMA accounts for 18\% of Brazilian gross domestic product (or US$ 425 billion), 31\% of Brazil's industrial domestic product and 25\% of the industrial labour force. Today, the region is the largest industrial centre in Latin America.

Despite its economic stature, there are considerable inequalities in income distribution in the metropolitan area: the richest 10\% of the population earned 30\% of the total income, and the poorest 50\% earned only 25\% of the total income in 1990. The unequal distribution of the economic benefits of urban growth in São Paulo has had a marked impact on the distribution of household environmental benefits resulting in "an inequitable burden of negative environmental impacts which affect the poor" (4).

São Paulo's growth and industrialization have also been marked by serious environmental problems. The deteriorating quality of environmental resources including air, water and land have been mentioned by various authors (4-6). At

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the macro-level, industrial air and water pollution have been tackled with some success. However, there are still serious problems with air pollution produced by motor vehicles and water pollution due to inadequate treatment of sewerage. Solid waste collection has also been a matter for concern, because the annual increase in quantity has not been followed by a corresponding increase in waste treatment sites (2). Erosion, flooding, soil contamination, mudslides, and noise pollution are other environmental problems in the region (2, 4).

To set the linkage of environment and health data in São Paulo in its broader health context, we shall describe the aggregate epidemiological profile of the city. In the City of São Paulo in 1992, only 4% of all registered deaths were due to infectious and parasitic diseases, whereas 33% of all deaths were due to diseases of the circulatory system, 12% to respiratory problems, and 14% to external causes. Other cause groups accounted for the remaining 37% of all registered deaths (Fundação SEADE - internal files).

In general, São Paulo is a city of considerable industrial and economic strength, with emerging problems of the macro environment including air pollution. In socio-economic terms, the city is characterized by large disparities in wealth between the rich and the poor and this has repercussions for social and environmental conditions at the micro-level. Bearing in mind the city’s overall context, we will now explore monitoring of the environment and health and the use of data linkage in São Paulo.

**Data Linkage**

The type of linkage possible using existing data is dependent on the range and quality of information available and accessible. There are, broadly, 3 types of data required for the linkage of environment and health data: numerator data (i.e., data on health events - ideally clinically-diagnosed mortality or morbidity); denominator data (i.e., data on the population at risk); and lastly, the exposure data (i.e., data on the environment to which the population is exposed).

In order to explore the possibilities and practicalities of data linkage we will review information in São Paulo under the general themes of: sources of data; quality of data; and monitoring and data linkage. The discussion focuses on data linkage at the ecological level, that is analysis based on grouped data (rather than individual data).

**Sources of data and availability**

Urban areas of both developed and developing countries are often characterized by their multiplicity of agencies, and if they are regional or national capitals, by the presence of academic institutions. Consequently, there is often no shortage of information collected on health-related conditions and on the urban environment. São Paulo is no exception.
Denominator data (population)

Census data are normally the main source of population estimates and can be used to provide approximate information for denominators in rates of mortality and morbidity. One advantage of census data is that they are based on total counts of the population and are regularly undertaken (allowing time trends to be analysed). Disadvantages occur if the census occurred many years prior to a current analysis. Mobility of the population can be difficult to estimate accurately and may differ widely between sub-groups.

Brazil’s population census (most recent in 1991), is carried out every 10 years, and compiles the following information: resident and/or present population (in other words, de jure and/or de facto population), distribution by age, sex, marital status, religion, race, urban/rural condition, education, place of birth, relation to the head of the household, etc. (7).c

Population enumeration is based on the smallest geographical fraction (census units) but results are published by districts or municipalities. The SPMA is formed by 139 districts with 96 of them in SPC. Data on census units are available upon request. Access to the data is obtained by published reports or by terminal and disks. There is no charge to obtain general population data, but IBGEf has set fees for special tabulations. The 1991 Census has recently made available data on age structure of the population.

Ad hoc surveys have also been used as sources for population estimates. PCV (Pesquisa de Condições de Vida – survey of living conditions) (5)g and Pesquisa Origem Destino (origin – destination survey)h are two such surveys that can provide population data, and are used particularly for local planning in inter-censal periods.

Numerators: health data on mortality and/or morbidity

Sources of routine numerator data on mortality and morbidity can be diverse. Routine numerator data can be obtained primarily through vital events information, infectious disease notification and facility-based information. Here we will discuss only vital events and facility-based information.

Vital registration of events (mortality). Annual analyses of mortality data in São Paulo are made by Fundação SEADE, a division of the São Paulo State Planning Secretariat. Death certificates are compiled on a monthly basis from civil registers (cartórios) and deaths are coded by place of residence of the deceased.i Data on age, sex, place of occurrence, main and associated causes of death are also available. Data on yearly mortality is obtained from SEADE upon request or through their annual publications. Mortality data can also be acquired from the Ministry of Health, but their data are always produced after SEADE’s data. Where registration of death events is a condition for burial in controlled cemeteries, and all cemeteries are controlled by government, then registration of events is more comprehensive.

Daily enumeration of deaths is also compiled through the São Paulo Municipal Secretariat of Health (SEMA), where PROAIM, a municipal project to improve death certification, obtains death certificates sent by city funeráriasj 24 hours after the occurrence of every death. PROAIM data are based on 56 districts and subdistricts in SPC. Access to these data can be obtained through SEMA’s computer terminals.

Morbidity data. Morbidity data are produced routinely in public and private health facilities with an official compilation mechanism embracing public and private hospital admissions. Data on outpatient care are officially compiled only for public facilities. A recent household survey (the PCV) showed that only 40% of the families living in the SPMA are exclusive users of the public health system (publicly-owned facilities plus privately-owned facilities financed by public money). The other 60% have individual private health insurance, are enrolled in company plans or use private facilities on an ad hoc basis. This official data base thus does not contain outpatient data on 60% of the population, making routine morbidity data incomplete in terms of the population’s health experience.k

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c Basic data are collected for the total population, but more specific information, for example, fertility, mortality, migration, labour force, is collected only for a sample, which, until 1980, represented 23% of the population. In the 1991 Census this sample varied between 10 and 20%, depending on the size of the city.

f IBGE (Brazilian Institute of Geography and Statistics) located in Rio de Janeiro is a federal government unit in charge of Census operations.

g The Pesquisa de Condições de Vida collected data on family income, labour market, housing, access to health care, education and property for 5,000 households in the SPMA.

h The Pesquisa Origem Destino was carried out by the SPMA in 1987. This research resulted from a survey of 26,000 households and used the population projected by Fundação SEADE for 1990 as its expansion factor.

i SEADE codes mortality data for all municipalities in the SPMA. In SPC place of residence is disaggregated into 56 districts and subdistricts. There are plans to adjust SPC coding to the 96 new districts.

j Special shops that organize funerals, make and sell coffins. They are private in the majority of Brazilian cities. In São Paulo City for historical reasons they belong to the public sector.

k The “Hospital data base” (SIA-SUS) gathers data on admissions to the public-sector hospitals and the “Ambulatory data base” (SIA-SUS) registers data from appointments made with public-sector outpatient facilities. Both systems were set up by the Ministry of Health, but State Secretaries have their own data bases. In São Paulo, the State Health Secretary runs a very well structured information system (CIS).
Health surveys have been carried out to obtain data on morbidity. In the 1980s, IBGE undertook 2 surveys (8). Cancer registers are also available. The population based register was established in 1969, but there has been discontinuity in its work and the latest data are from 1978. There are also hospital registers in the main cancer units in SPC. Access to this type of data can be obtained through ad hoc reports and publications.

Exposure data
There is a diverse range of sources for environmental exposure data – at the micro-level, data are obtainable through service providers, and intermittently from the census or other large-scale household surveys. Macro-environmental problems are often monitored through agencies set up for the purpose.

Service-based data. Most cities maintain records of environmental services such as water supplies, sanitation, electricity connections, sewerage connections and solid waste disposal. These data serve to give a broad idea of the environmental conditions faced by the population in their homes or neighbourhoods. At the very least, agencies dealing with environmental services will have information on the more affluent areas of town where services are regularly provided. Agencies which provide information on the supply of an amenity to an area may not routinely collect data on aspects of quality, quantity or regularity of that supply.

Census or large-scale household survey data. The main advantage of exposure data culled from the census is that information is often detailed and the measurements apply to individual households. Since one of its aims is to represent the whole population, the census may also be the most comprehensive and detailed available source of micro-level environmental exposure information. Depending on the degree of disaggregation of data required, an advantage of using exposure data from the census is that the geographical breakdown of the data is compatible with the breakdown of census-based denominator data (thus enhancing the reliability of the linkage of the two types of data). A disadvantage of census-based exposure (and population) data may be that geographical disaggregation of information is not compatible with the disaggregation of data on health events such as mortality (often reported by administrative/political districts).

Spot-monitoring systems. Some cities now employ monitoring systems which monitor an environmental hazard at certain geographical locations. Such monitoring usually documents a macro-environmental problem, for example air or water quality. If carried out consistently over time this monitoring can gauge trends in conditions. A limitation of such spot monitoring may be that a small number of stations or points of monitoring may not be able to represent accurately the overall profile of conditions in a large area.

In São Paulo, both micro-level and macro-level environmental hazards are monitored. At the macro-level, air pollution is monitored by an agency set up for the task. Micro-level environmental health conditions are monitored routinely by service agencies.

Macro-level exposure data: air pollution. CETESB (the State of São Paulo Environmental Agency) is the main source of routinely-collected air pollution data in the SPMA (9). There are 22 automatic and 7 manual stations collecting air pollution data in SPMA. 60% of the automatic and 86% of the manual stations are in SPC. Because air quality is only monitored close to the stations, the results are not representative of the whole district. The majority of stations are placed at busy roads in the town’s centre.

CETESB provides data on air pollution each day to the media plus a forecast of pollutant dispersion for the next 24 hours. Basing calculations on the Pollutant Standard Index (PSI) created by the Environmental Protection Agency (EPA) of the United States of America, CETESB computes an index which expresses the quality of São Paulo’s air within 6 categories: “good”, “regular”, “inadequate”, “bad”, “worse” and “critical”. CETESB also adopts criteria for controlling daily acute episodes of air pollution based on 3 category levels – “attention”, “alert” and “emergency” – for each pollutant.

Micro-level exposure: socio-environmental data. At the micro-level we focus on 5 socio-environmental hazards in São Paulo which have differential impacts on households in the city. These indicators of environmental health hazard were selected by local planners, academics and service agency staff in a forum, on the basis of their relationship to micro-level environmental health problems in the city (as perceived by participants). Measured at the ecological level (ecological in the sense of using geographical data to compare environmental conditions between districts within the city), the data used to compose an index of socio-environmental deprivation in the city were “income” = average per capita income; “education” = percentage of illiterates and people who did not complete primary school; “sewerage facilities” = percentage of houses linked to central sewerage; “water supply” = average per capita water consumption; and “housing” = average number of persons per house. Using a complex of indicators to measure socio-environmental hazard reflects both the opinions of planners and policy-makers in São Paulo and a concern about individual data quality.
To analyse the effects of differentials in environmental conditions within the city, differences in conditions and health between areas in the city can be mapped, provided that geographical references for data are compatible. São Paulo City has until recently been divided into 56 districts and sub-districts, the traditional geographical bases for census data and vital registration. Some environmental service agencies use their own system to divide the city: for example SABESP (the water and sanitation agency) uses 310 "real estate sectors".

The data used for monitoring micro-level environmental problems in São Paulo can be obtained from the following sources: (i) Pesquisa Origem-Destino provided disaggregated data on "income" and "education" for each district and sub-district; (ii) data on the "water supply" and "sewerage facilities" variables were collected at SABESP; and (iii) the 1991 Population Census gave us data on housing density. Micro-level data on household or neighbourhood conditions can also be obtained through surveys organized by state or metropolitan departments or by IBGE. National household surveys carried out by IBGE started in 1981 with the theme "health", and an annual survey has been carried out each year since.1 IBGE data are accessible through publications, disks, reports and special tabulations. The national census also collects socio-environmental data every 10 years.

Data quality

Denominator (Population)

Monitoring environmental and health conditions, particularly over time and within small areas, requires an understanding of population mobility, since quite often an individual will face a risk in one location but may fall ill or die in another area. The linkage of data on a particular environment with the health of those who, at any one time, live in that environment is therefore difficult. No routine information about previous residence (i.e., specific location) is available routinely in Brazil. Data on population mobility within São Paulo are largely unavailable, but may be derived from the 1991 census.

In terms of completeness of denominator data, there is an overall 5-10% under-enumeration in the Brazilian census. This under-enumeration is distributed unevenly by area and age groups. The homeless in São Paulo are a potential source of substantial under-enumeration in census counts. This has the effect of creating an under-estimation of denominators, with particular impact on data from central areas of the city where higher concentrations of the homeless attempt to subsist. There are claims in SPC that the 1991 census under-enumerated considerably, although this claim is refuted.

Numerator (mortality and morbidity data)

Routine vital registration data on deaths in São Paulo are excellent overall (10). They are estimated to be 99% complete, with only limited area-specific problems. There is also satisfactory accuracy in the reporting of the main cause in the death certificate (11). Area-based data, particularly in the central areas of São Paulo, are affected by the deaths of the homeless, who are not registered in the census, but appear in mortality figures in civil registers (cartórios) in the centre of the city, making rates appear high in these areas. Peripheral areas in the metropolitan area, such as the District of Parelheiros in SPC, may also be affected.

Exposure data

Macro environment: air pollution. Air pollution is varied in its nature – it can be indoor, outdoor or personal. In terms of health-threatening pollution in the short-term, tobacco is probably the main air pollutant in urban areas to cause respiratory diseases (12). It also contributes to many other diseases outside the respiratory system. Indoor pollution is another factor in health problems. Institutional geographical information on these two sources of pollution is scarce in SPMA. Air pollution monitoring activities in the SPMA collect data only on outdoor pollution. The monitoring stations in São Paulo gauge only very localized problems, reflecting each monitoring station's surroundings. Most stations are located along busy roads and are concentrated in the central areas of the city.

In terms of completeness of air pollution monitoring, there is also variation among the monitoring stations in continuity of data collection. For example, Lapa station monitored 360 days in 1992 whereas Santana monitored only 251 days that year. In addition, not all stations monitor the same type of pollutant. In SPMA only one automatic station (Parque São Pedro) and the 2 mobile laboratories are able to measure all common pollutants. The severity of the problem over a larger area cannot be assessed with a sparse set of observations. Monitoring should be complemented with spot surveys, but financial limitations have restricted such surveys.

Socio-environmental data. Routine data on micro-level environmental conditions in São Paulo are, on the whole, very good and a large number of sources (mostly academic studies) are available to cross-check and corroborate data. Limitations of routine information on socio-environmental conditions are related to the level of disaggregation

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Adopted the new boundaries has yet to be which conceals differentials in environmental conditions and possibly health impacts within districts. The 1992 revision of internal city boundaries into 96 districts was intended to solve this to a degree. Adoption of the new boundaries has yet to be implemented by several agencies, most notably the vital registration system, which still uses 56 divisions for its data analysis.

A more difficult problem is related to the sensitivity of existing data to reflect accurately environmental quality at the micro-level. To give an example of problems with data sensitivity in São Paulo, and using access to sanitation, despite evidence of some differentials between areas within the city, routine information on “access to sewerage facilities” do not give an accurate picture of distinctions in service quality between the extremely vulnerable and the privileged in the city. SABESP data indicate that in more than 50% of the districts and sub-districts in São Paulo, 90% of the households have “connections” to sewerage facilities. In contrast, and at greater degree of specificity, the results of a major household survey for the metropolitan region showed that only 40% of the favela households have access to sewerage facilities and 25% of the cortiços households have no access to this service (5). Aggregate data on districts containing small pockets of favela households and cortiços do not reveal enough about conditions there.

Existing health and environment monitoring

Monitoring of micro-level environmental conditions

Despite the fact that over 40% of the population are known to be living in poverty, environmental problems at the micro-level in São Paulo have not, until recently, been “monitored” in the sense of (publicly) documenting socio-environmental conditions and using monitoring data to act. However, to the degree that each agency is aware of the coverage and quality of its particular environmental service, individual aspects of environment at the micro-level have been monitored. For example, SABESP officials have extensive data and are aware of the distribution of their services and service quality. Similarly, the Housing Secretariat monitors the degradation of housing stock into cortiços and maps and monitors the development of favelas. Each agency monitors conditions for its own purposes, often linked to maintenance of agency-specific environmental and professional standards, and also to financing of service delivery. Data have not been shared between agencies until recently.

Despite limited communication among agencies about the socio-environmental conditions which they each document individually, there have been several initiatives over the past decade to compile broad-ranging data on socio-environmental conditions. The municipal planning secretariat (SEPLMA) compiles and has access to diverse information on services and uses it to estimate future needs. SEMPLA does not, other than in a discretionary sense, have control over the delivery of services to areas with poor environmental facilities.

In 1993, a collaborative initiative was set in place, involving SEADE (the state statistical agency), SEMPLA (the municipal planning secretariat), SABESP (water and sanitation), the municipal Housing Secretariat, São Paulo State Education Secretariat, and the London School of Hygiene and Tropical Medicine (1). This initiative aimed to create a linked data base, which monitored socio-environmental conditions within the city for one year (1992-93), both through developing compatible maps of the distribution of health and environmental conditions by district and through the construction of an index of socio-environmental deprivation based on routine, existing data. The index measured relative socio-environmental conditions between districts and established 4 zones of socio-environmental quality which were then linked to health conditions within the city.

According to this analysis, 43.8% of São Paulo’s population live in the quartile of districts with the worst socio-environmental conditions (Zone 1). They have a low level of education and income, have limited access to sewerage facilities, consume less water per capita and live in higher-density housing. Zone 4 has the best socio-environmental conditions in the city, with 9.2% of São Paulo’s population. Zones 2 and 3 contained 34 and 45% respectively.

Table 1 shows that large differentials in conditions exist among areas in São Paulo. For example, on average, per capita income is over 3 times higher for residents of Zone 4 compared to income for residents of Zone 1. Differences in education also exist, with levels of illiteracy ranging from 28.1% in

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Adapted a method developed by the United Nations Human Development Report, 1992 to derive a Human Development Index.

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Zone 4 (the best) to 40% in Zone 1. Differentials in water consumption are striking: in Zone 1 only 4.3 m$^3$ of water are consumed per day per capita. In contrast, over 20 m$^3$ are consumed per day per capita in Zone 4.

The majority of districts in Zone 1 (the most deprived) are on the periphery of the city, while the centre houses the most privileged (on average). The distribution of socio-environmental conditions should be borne in mind as we discuss the monitoring of the macro-environmental problem of air pollution.

**Macro-environmental monitoring: air pollution**

Air pollution monitoring started in 1965 in 3 industrial municipalities of the SPMA (9). Monitoring in São Paulo City started 3 years later with the measurement of sulphur dioxide (SO$_2$) and smoke levels at only one site (13). There were 14 sites in 1977 (reduced to 6 in the early 1980s) with 3 of them providing information to Global Environment Monitoring System (GEMS). In 1981, the State of São Paulo Environmental Agency (CETESB) installed automatic monitoring devices at 25 new sites (including Cubatão, a city outside the SPMA), an improvement on the previous manual method.

In 1994 the monitoring network consisted of 12 automatic and 6 manual stations in SPC and 10 automatic and 1 manual station in other municipalities of the SPMA. There are also 2 mobile laboratories which operate automatically. The automatic network measures the following features: respirable particles (PM$_{10}$), sulphur dioxide (SO$_2$), oxides of nitrogen (NO$_x$), ozone (O$_3$), carbon monoxide (CO), hydrocarbons (HC), wind speed (WS) and direction (WD), humidity (H) and temperature (T). The manual network measures SO$_2$ and smoke levels, while at 9 automatic sites, suspended particulate matter (SPM) is measured manually by the high volume samplers. Table 2 shows the configuration of the automatic network in the SPMA.

**Table 1**

<table>
<thead>
<tr>
<th>Zones</th>
<th>Average per capita income (minimum wages)</th>
<th>Average % of illiterates &amp; incomplete primary school</th>
<th>Average % of houses linked to the general network</th>
<th>Average per capita water consumption (m$^3$)</th>
<th>Average number of people per house</th>
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<tbody>
<tr>
<td>Zone 1</td>
<td>2.1</td>
<td>40.0</td>
<td>64.3</td>
<td>4.3</td>
<td>3.8</td>
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<td>Zone 2</td>
<td>3.2</td>
<td>35.5</td>
<td>81.8</td>
<td>6.2</td>
<td>3.7</td>
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<tr>
<td>Zone 3</td>
<td>4.3</td>
<td>32.8</td>
<td>94.2</td>
<td>11.5</td>
<td>3.4</td>
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<tr>
<td>Zone 4</td>
<td>7.2</td>
<td>28.1</td>
<td>98.7</td>
<td>20.6</td>
<td>2.8</td>
</tr>
</tbody>
</table>


Emissions inventory is an important activity in the air pollution control and monitoring process. Emissions are associated with power generation and industry, motor vehicle traffic and domestic solid fuel. São Paulo is considered to have good availability of emissions inventories as shown by the Urban air pollution in megacities of the world (13).

Table 3 presents a summary of the relative contribution of various emission sources and their respective pollutants.

Topography and climatic characteristics have an important influence on air quality as they contribute to the dispersion of air pollutant emissions. Varied topography, proximity to the sea, surrounding mountains, the "street canyon" effect (busy roads with tall buildings in both sides of the road preventing dispersion of low level emissions) and thermal inversions are the main factors which influence the dispersion of air pollutants in São Paulo. Frequently during the winter du in São Paulo (May to August), inversion layers form above the ground and trap pollutants, which in turn aggravates the thermal inversion. CETESB has a special scheme for monitoring air pollutant dispersion in winter.

CETESB has data on first and second maximum daily pollutant levels, arithmetic and geometric means, and number of monitored days since 1988. There is also information on the number of days when pollutant levels were above national standards and indications whether these levels triggered the categories of critical points of "attention", "alarm" and "emergency".

Twenty-one fixed stations monitor respirable particles. In 1992, 15 of these reported days when levels were above national standards (50 g/m$^3$). The highest annual arithmetic mean was found in 1990.
Table 2
Configuration of the automatic network in the SPMA

<table>
<thead>
<tr>
<th>No</th>
<th>Station location – Emplacement de la station</th>
<th>PM$_{10}$</th>
<th>SO$_2$</th>
<th>NO</th>
<th>NO$_2$</th>
<th>CO</th>
<th>HC</th>
<th>O$_3$</th>
<th>Humidity – Humidité</th>
<th>Temperature – Température</th>
<th>Wind speed – Vitesse du vent</th>
<th>Wind direction – Direction du vent</th>
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<td>Parque D. Pedro</td>
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Source: Réf. Réd (9)

Table 3
Summary table of the relative contribution of different emission sources and respective pollutants

<table>
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<th>Pollutants – Polluants</th>
<th>Vehicles – Véhicules</th>
<th>Sources – Sources</th>
<th>Other – Autres</th>
<th>Total – Total</th>
</tr>
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<tr>
<td>CO</td>
<td>94%</td>
<td>3%</td>
<td>3%</td>
<td>100%</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>92%</td>
<td>7%</td>
<td>1%</td>
<td>100%</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>64%</td>
<td>36%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>40%</td>
<td>10%</td>
<td>50%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Réf. Réd (9)

Cerqueira César (92 g/m$^3$) reflecting traffic problems in the area. Smoke level is measured at 7 stations: only one of the stations had an arithmetic mean smoke level above the national standard in 1992. Suspended particulate matter (SPM) is assessed at 9 sites in the SPMA, using the high volume sampler collecting a 24-hour sample every 6 days. At 4 of these, the annual geometric mean levels of pollutant were found to be above the national standard. CETESB data indicate a decline in the levels of the 3 pollutants mentioned over the last 10 years (9).

For sulphur dioxide, none of the monitoring sites reported annual arithmetic means above stan-
Current health and environment data linkage activities

This section documents briefly the results of environmental and health data linkage, looking first—at the micro-level—at the health effects of the socio-environmental risks faced by the population of São Paulo. Macro-environmental monitoring and its linkage to health data are summarized.

Micro-level environmental problems: Health and environment differentials

We begin with the results from the recent data linkage of environment and health data in São Paulo (1). Results reflect the inequalities in conditions between the central, intermediate and peripheral areas of the city of São Paulo. They most strongly indicate the impact of an environment of poverty on the population, particularly for those who live on the outskirts of the city, both with respect to material symptoms of poverty in terms of access/non access to public services and to the added environmental risks attached to living in situations of social disadvantage.

The study results also suggest that São Paulo’s economic strength has not been able to provide benefits for a considerable proportion of its inhabitants. Fifty-nine per cent of São Paulo’s inhabitants (5 664 000 people) live in precarious housing (14) and approximately 16% of the people (1 536 000 people) have no access to sewerage facilities (SABESP, internal files, 1993). In a city which needs both a skilled, blue-collar workforce and an efficient army of white-collar workers to maintain good-quality industrial output, 33% (3 168 000) of its citizens are illiterate or have not completed primary school (15).

The study of socio-environmental zones for the City of São Paulo showed that approximately 44% of the population live in areas with the worst per capita income, with least access to sewerage facilities, lower water consumption per capita, highest population densities and the least education. Linking this information to mortality data revealed that people living in the worst areas had considerably higher levels of mortality than those living in areas with better socio-environmental conditions.

Looking at São Paulo’s health differentials by age group, there is significant room for improvement in the 0-4 year-old group, probably through preventing deaths by diarrhoea and pneumonia. Overall, respiratory and infectious disease account for the majority of deaths in this age group. Differentials between the zones are striking. Respiratory and infectious mortality rates are (respectively) 3.8 and 4.4 times greater for children in Zone 1 (the least privileged) than in Zone 4. It should be noted that infectious diseases represented only 2.6% of all deaths in São Paulo for 1992. However, these figures indicate that despite its status as one of the most successful examples of a city in an industrialized developing country, São Paulo has yet to conquer preventable child deaths in vulnerable population groups.

Perhaps the most alarming differential is in homicides which account for major excesses in mortality between socio-environmental zones. Violent deaths are a particular cause of concern for the poor: in 15-44 year olds in the worst socio-environmental conditions there were 3 428 violent deaths in 1992 (or 16.5/10 000) compared to 326 deaths in Zone 4, the wealthiest (7.8/10 000). This could be described as an “epidemic of violence” affecting the poor of São Paulo most severely. Overall in 1992 there were 3 759 deaths due to homicides (8/10 000 population). If we consider only males aged 15-24, the mortality rate for homicide was 19.5/10 000 in 1992. This rate is just below that in the United States (21.9), which has the highest rate for this age group of males among industrialized nations (16). It is probable that this “epidemic” is related to the environment of social disadvantage experienced by many in São Paulo.

Looking at older age groups, mortality patterns in the 45-64 year-old group show evidence of premature deaths from traffic accidents, cerebrovascular diseases and hypertension. There are significant differentials between socio-environmental zones. Increasing levels of mortality from diseases of the circulatory system in developing countries are often thought to indicate transition from diseases of poverty to diseases of affluence. Data from São Paulo corroborate increasing evidence that circulatory diseases cannot be called diseases of affluence: in São Paulo, as in developed countries, their impact is felt most severely by the poor. Data on differential mortality from circulatory diseases in São Paulo in 1992 indicate that in socio-environmentally disadvantaged Zones 1 and 2, residents experienced significantly higher rates of mortality compared to their wealthier neighbours in Zones 3 and 4.

Interestingly, differentials in mortality appear to diminish in the 65+ age group. It seems that the elderly die at similar rates whichever zone they reside in.

Ad hoc studies linking household environmental data with health data. Household-level differentials shown by this data linkage exercise (1) are supplemented by evidence from other studies. For exam-

ple. Monteiro (17) found that downward trends in infant mortality in the City of São Paulo during three decades (1950-1979) correlated strongly with trends in real minimum wages, improvements in water supply and access to health care. Other studies corroborate this broadly (18-20).

A Municipal Health Authority Report notes that mortality from external causes (road accidents, homicides and suicides) was the major cause of death in the 5-39 age group. Differences between sub-districts are shocking: the mortality rate from homicide is 11.3 per 100,000 in Jardim Paulista (a rich area) and 69.2 per 100,000 in Itaim Paulista (a poor area).

Macro-environment: air pollution and health data linkage
Currently, assessment of air quality consists of examining ambient air quality against established guidelines. This system is not based on previous local linkage of health and environment data and establishment of local standards but works on a “risk analysis” basis, where only environmental data is monitored and public health risk is extrapolated from international data and standards.

The main aim of monitoring air quality in São Paulo is to trigger emergency actions when pollutants in the atmosphere reach levels that may (according to international criteria) cause risk to public health. Control and monitoring activities in the SPMA are based on standards defined in 1976 by a State decree (9), the same standards set by the United States Environmental Protection Agency (EPA) (21).

There have been some critics of this approach, who argue that establishing standards based on foreign data suggests that the adverse effects of air pollution on human health are exclusively dependent upon the air pollutant concentration, and are not influenced by local conditions.7 In reality, local climate, socio-environmental conditions and lifestyles in São Paulo are all likely to affect the relative influence of air pollution on health.

Although local air pollution and health data are not linked routinely, several ad hoc studies have been undertaken in São Paulo to look at links between pollutant levels and morbidity and mortality (22-24).

The studies by Ribiero (22) and Sobral* assessed pollutant levels in terms of respiratory, infectious or ventilatory symptoms in children, while the other two (23,24) seem to show correlations between increased levels of particulate matter, SO₂ and CO and cases of respiratory and cardiovascular disease admitted as emergencies at local hospitals. Finally, Saldiva et al., through a time series ecological study, found significant association between mortality in the elderly and respirable particulates from pollution (25), and robust association between child mortality and NOₓ levels (26).

Conclusions: potential linkage, monitoring and policy activities
One of HEADLAMP’s main aims is to provide decision-makers with the necessary tools to monitor environmental health problems and to assess the effect of their policies. There is an assumption that action will be facilitated by data linkage and the development of indicators. Environmental health measures will “give explicit policy-related information”. This final section briefly discusses the potential policy implications of the HEADLAMP idea.

Current environmental policy and plans
Air pollution. São Paulo has achieved some success in control of its macro-environmental problems. Control of industrial pollution, dating back two decades, (high-sulphur fuel oil was replaced by low-sulphur fuel, biomass, natural gas or electricity) has reduced the emissions of SO₂ by a factor of over 5 since 1976 (13). This change has allowed for considerable improvement in the SPMA’s air quality. Motor vehicle traffic is now responsible for the largest proportion (64%) of SO₂ emissions (9).

The National Alcohol Programme implemented in 1979 brought important changes in air quality in Brazil. In 1989 half of the motor vehicles in the SPMA were running on alcohol and gasoline and 22% of vehicles used alcohol alone. Overall it can be said that the introduction of alcohol decreased emission of CO, NOₓ, HC, SO₂, increased amounts of aldehyde and eliminated emissions of lead. Since 1979, CETESB has done special surveys to assess these changes. It is likely that increases in motor vehicle registrations and in the proportion of vehicles which run on diesel mean that current reforms will not contribute much to further improvement in vehicle pollution. The Programme for Controlling Air Pollution due to Motor Vehicles is an attempt to solve the problem and it is expected to be in full effect by 1997.

Socio-environmental conditions. Disparities in socio-environmental conditions between groups within São Paulo have been the subject of discussion for

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* These causes represented only 1.5% of all causes of death.
many years in the city (27, 28). Significant steps have been taken towards improving the coverage of basic environmental infrastructures within the city. To a large extent, this has been achieved: piped water and sanitation facilities extend into many of the favelas and the corticos; and primary health initiatives have increased coverage by immunization campaigns within the city. The combination of these public health actions has had a marked effect on infectious diseases throughout the city, particularly among children. However, as we have discussed, disparities in conditions between groups within São Paulo still exist and these appear to have significant ramifications for the health profiles of both children and adults.

**Future planning.** São Paulo is at an opportune moment to develop policy-oriented monitoring systems of its environmental and health conditions. For the first time, a comprehensive plan aimed at sustainable development of the city, has been put forward by the authorities. The Metropolitan Plan for Greater São Paulo (2) stresses the need to look for long-term, not short-term solutions to the city’s problems. The plan attributes 4 dimensions to development: (i) economic growth; (ii) social equity; (iii) preservation and improvement of quality of life; and (iv) protection of natural resources. The main aim of the plan is to guarantee the sustainable future development of the metropolis.

Within this context there is a rising popular concern for the quality of São Paulo’s macro- and micro-environments. The consequences of inequalities in socio-environmental conditions are clear from documented health data; the impact of these and the potential consequences of poor air quality are widely reported in the popular press and academic circles.

At the macro level, according to recent research, the population perceives poor air quality as a principal aspect of environmental degradation in the SPMAs (28). Jacobi found that air pollution was perceived as the main environmental problem of the city, followed by urban violence and the shortage of health services. It is important to note that environmental priorities, and definitions of the problem, differed substantially according to the socio-economic status of the respondents. In the wealthiest strata, 71% of householders ranked air pollution as their number one problem, referring to vehicular emissions as their main air quality concern. In contrast, 46% of households in the poorest strata perceived air pollution to be their major environmental problem—these households were referring to problems of air quality in terms of dust, smoke and foul smells.

As the case of São Paulo shows, there are extensive data available on environmental conditions and health in the metropolis. Routine environmental data have not, until recently, been linked to health outcomes.

In the case of our macro-environmental risk, air pollution, monitoring is carried out currently on the basis of risk analysis relying on international guidelines to set local standards of suspected health effects. *Ad hoc* studies of air pollution and health suggest local risk, but data linkage has not been established routinely.

For micro-environmental problems, *ad hoc* studies have documented differentials in health and environment between groups within the city for some years, but until recently the linkage of diverse, routine data has not been accomplished. The intra-urban environment and health study in São Paulo demonstrated the extent of micro-environmental problems and health effects of these on the population of the city. Perhaps more importantly, the study’s methods can be seen as a pilot attempt to establish the feasibility of linking diverse environmental and health data and developing routine communication between diverse data sources. By working directly with selected planning and environmental service agencies and developing linkages over time, the study has facilitated environmental and health data linkage on a more systematic basis for the future.

Despite São Paulo’s achievements in establishing good information systems, there is still potential for improvement in information systems. In order to understand the priorities of different groups within the city, planners have expressed a need for the development of more compatible and interlinked data systems, for the express purpose of creating integrated urban policies. This fits closely the recommendations of *Agenda 21*, “to establish, as appropriate, adequate environmental monitoring capacities for the surveillance of environmental quality and the health status of populations”. In order to move towards integrated information systems, São Paulo still needs to develop its capacities for linked monitoring of environmental and health problems. Among the priorities are the creation of geographically compatible data bases for environmental and health sources and the establishment of a routine system for communicating and publicizing linked health and environmental data.

Stepping back to the macro level, São Paulo seems now to have an operational risk analysis system and to have acted concertedly on some forms of air pollution. Whether this has been achieved on the basis of actions guided by monitoring or on the basis of problems perceived at a political level, is not clear. Given HEADLAMP’s thesis that health and environmental monitoring is a necessary catalyst for environmental change, this is an important unanswered question.

Despite monitoring of the environmental problem of air pollution at the macro-level, there are also still gaps in understanding of air pollution and its specific effects on the population of São Paulo.
For example, there are still significant questions related to the specific interactions of the local climate with fluctuations in pollution and effects on health. Perhaps more importantly, there is almost no evidence of the relationship that the macro and micro problems may have with each other. There is international evidence, for example, that the poor may face higher health risks from exposure to air pollution (4). It is not clear whether this is true in São Paulo.

Finally, and in relation to HEADLAMP’s thesis that monitoring is followed by policy, it should be stressed that it is not clear whether monitoring an environmental problem (and/or its health effects) has a substantial impact on environmental policy, nor if it does, how this occurs. It has been argued that only one of the four key mobilisers of policy change is technical advice based on “information, analyses and options” (29).

How might the complex interaction of information and policy development relate to São Paulo and its environment? For the macro-problem of air pollution, São Paulo is in a critical stage. Risk analysis suggests that the city centre is the most vulnerable area and that vehicular pollution is the culprit. Vehicles in São Paulo are owned mostly by the wealthy. Will the wealthy willingly compromise their expression of economic gain – the car – for health benefits? The historical short-term reaction of the wealthy to air pollution in the centre of cities is to try to retreat to insulated suburbs, commuting (mostly by car) to a centre which may be increasingly characterized by office blocks and run-down housing lived in by the poor. It is not clear if this is the future for São Paulo, nor what role monitoring of the problem might play.

Finally, monitoring of health and environment linkages has to be set within the context of public health priorities facing populations in the short and long term. Policies must be seen in the context which shapes them. To some extent, the way in which policy makers respond to the micro-level environment of poverty faced by many of São Paulo’s citizens will inform responses to macro problems. In the short term São Paulo’s health profile is characterised by diseases of the elderly (heart disease and neoplasms), with an adult health profile dominated by diseases of the social environment – violence being the major threat. Currently, violence ranks second to air pollution as a major environmental problem perceived by the rich and poor in the city (28). Both are perceived urban environmental threats to health, but it is violence that has the more substantial impact on population health at present in São Paulo, with significantly higher risks among the poor.

At present, the wealthy in São Paulo ensure their safety from the environmental health threat of violence with security systems. In terms of environmental strategy, it is a not dissimilar attitude to that of wealthy 19th-century Londoners who built parks to insulate themselves from the ill-understood “miasmic” diseases of their poorer neighbours (30).

There is a danger that both the complex micro-environmental problems and the macro-environmental questions may be dealt with in the same way. Air pollution may have substantial effects on people’s health in São Paulo, but the question remains: who pollutes and who pays and will pay with their health? Given the current inequalities in the structure of São Paulo’s society, will monitoring the environmental impacts of air pollution really catalyse the rich into curbing their vehicle use in order to protect the health of the whole society? It is this question which is at the heart of the debate on monitoring environment and health – a question which faces many cities. Improving methods to monitor problems is just one step – an equally fundamental question is how to use that information to influence policy.

**Summary**

This article addresses the development of data linkage methods for the analysis of urban environmental health problems and the development of appropriate policies and discusses, based on existing experience of data linkage in São Paulo (Brazil), the potential for routine environmental health monitoring and management in a major developing country industrial centre. The article looks briefly at two major environmental health problems in São Paulo. First, air pollution which has potential impacts on health of the whole population, and second, environmental differentials in conditions between groups within cities, which have substantial health effects on the economically deprived. The article argues that the health impact of environmental differentials in São Paulo is large, but unmonitored as a serious environmental health threat. In contrast, air pollution is monitored routinely, although its health effects are relatively small at present. The paper concludes with a discussion of policy implications of environmental health monitoring – which potentially require a substantial shift in attitudes of the urban wealthy.

**Résumé**

**Santé et environnement à São Paulo (Brésil) : méthodes d’appariement des données et politique adaptée**

Cet article traite de la mise au point de méthodes de raccordement des données pour l’analyse des problèmes de salubrité de l’environnement en milieu urbain et de la conception de politiques appropriées. À partir de l’expérience acquise à São Paulo en matière de raccordement des données, il étudie les possibilités de surveillance continue et de gestion de l’hygiène de l’environnement dans un grand centre industriel d’un pays en développement. Deux grands problèmes de salubrité...
de l'environnement à São Paulo sont brièvement exposés : d'une part, la pollution atmosphérique, qui a des effets potentiels sur la santé de toute la population, et d'autre part, les conditions écologiques plus ou moins bonnes dans lesquelles vivent les différents groupes de citadins, qui ont d'importantes conséquences sanitaires chez les classes défavorisées. Malgré son ampleur, l'impact sur la santé des différences écologiques à São Paulo n'est pas objet d'aucun contrôle, alors qu'il s'agit d'un grave danger pour la santé. En revanche, la pollution atmosphérique est surveillée de manière systématique, bien que ses effets sur la santé soient à l'heure actuelle relativement faibles. L'article se conclut par un examen de la stratégie qui implique le contrôle de la salubrité de l'environnement – par exemple, un changement profond d'attitude chez les citadins plus favorisés.

References/Références

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