

Nelson Gouveia

Rogerio Ruscitto do Prado

Health risks in areas close to urban solid waste landfill sites

ABSTRACT

OBJECTIVE: To evaluate the association between living close to solid waste landfill sites and occurrences of cancer and congenital malformations among populations in their vicinity.

METHODS: Deaths among people living in the municipality of São Paulo, Southeastern Brazil, between 1998 and 2002 were selected and geocoded, according to selected causes. Over the period evaluated, there were 351 deaths due to liver cancer, 160 due to bladder cancer and 224 due to leukemia, among adults, 25 due to childhood leukemia and 299 due to congenital malformation, in areas close to landfill sites. Buffer zones of radius 2 km around the 15 sites delimited the areas exposed. Standardized mortality ratios for each outcome were analyzed in Bayesian spatial models.

RESULTS: In a general manner, the highest values for the standardized mortality ratios were found in more central areas of the municipality, while the landfill sites were located in more peripheral areas. The standardized mortality ratios did not indicate any excess risk for people living in areas close to solid waste landfill sites in the municipality of São Paulo. For landfill sites in operation, there was a greater risk of bladder and liver cancer, and death due to congenital malformation, but without statistical significance.

CONCLUSIONS: No increase in the risk of cancer or congenital malformations was found in areas in the vicinity of urban waste dumps in the municipality of São Paulo. The weak associations and the imprecision of the estimates obtained did not allow any causal relationship to be established.

DESCRIPTORS: Environmental Risks. Housing. Sanitary Landfill. Solid Wastes. Cause of Death. Neoplasms. Mortality Rate. Geographic Information Systems.

INTRODUCTION

Waste or garbage is any material generated by human activity that is considered to be useless, superfluous, valueless or unwanted and is disposed of in the environment. After collection, this waste may be dumped into landfill sites or destined for composting, incineration or recycling.^a Solid waste generated in urban centers may contain both domestic and commercial waste, along with industrial waste, thus constituting a complex mixture of different substances, of which some are hazardous to health.

After solid waste has been dumped in landfill sites, it may compromise the soil, water or air quality because it is a source of volatile organic compounds, pesticides, solvents and heavy metals, among other substances.⁸ Decomposition of

Departamento de Medicina Preventiva.
Faculdade de Medicina. Universidade de São Paulo.
São Paulo, SP, Brasil

Correspondence:

Nelson Gouveia
Departamento de Medicina Preventiva
Faculdade de Medicina
Universidade de São Paulo
Av. Dr. Arnaldo 455 – Cerqueira Cesar
01246-903 São Paulo, SP, Brasil
E-mail: ngouveia@usp.br

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^a Associação Brasileira de Normas Técnicas. Resíduos sólidos – classificação – NBR 10.004. Rio de Janeiro; 1987.

organic material present in garbage results in the formation of leachate, which may contaminate the soil and groundwater. Toxic, asphyxiating and explosive gases may also be formed, which accumulate underground or are expelled into the atmosphere.

In a general manner, landfill sites can be classified as sanitary landfills, controlled landfills and open dumps. Sanitary landfills use technologies that minimize the environmental impact and possible risks to human health. For example, the ground may be impermeabilized to avoid infiltration by percolating liquids. In controlled landfills, the garbage is merely covered with earth, without any measures for collecting and treating leachate and biogas. In open dumps, the deposition of waste does not follow any operational standards and is done in the open air.^b According to the National Basic Sanitation Survey (PNSB,^c 2000), carried out by the Brazilian Institute for Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE), the final destination of 47.1% of all the garbage collected in Brazilian municipalities is sanitary landfill sites, while 22.3% ends up in controlled landfills and 30.5% in open dumps.

Urban solid waste landfill sites have been considered to be potential sources of human exposure to toxic substances. The main routes for human exposure to the contaminants present in landfill sites are through dispersion in the ground and in contaminated air,¹⁹ and through percolation and seepage of leachates.⁴ Leaching occurs not only in landfill sites that are in operation, but also after they have been deactivated, given that the organic substances continue to degrade. Despite the lack of consistent evidence regarding large-scale exposure of populations,¹⁸ studies have indicated the presence of high levels of some organic compounds and heavy metals in areas close to landfill sites¹⁷ and in the blood of individuals living nearby these landfills.¹⁶

Studies using geographic or spatial approaches have suggested that there is an association between living close to solid waste dumps and health-related effects. Higher risk of liver, stomach, lung, prostate, kidney and pancreatic cancer and of non-Hodgkin lymphoma has been reported among individuals living close to such dumps.^{9,10,15} Nonetheless, controversy exists regarding the evidence^{11,13} and the data is insufficient to confirm or dismiss the possibility of higher risk of cancer associated with such exposure.

Other studies have examined possible associations with adverse outcomes from pregnancy, such as occurrences of congenital abnormalities,^{2,5,6,12,14} low birth weight,⁵

abortion and neonatal death.^{3,7} These studies have generally found small excess risks that have often been lacking in statistical significance.

The municipality of São Paulo is the biggest generator of domestic waste in Brazil, producing around 12,500 tons of garbage per day.^d Currently, most of this material is taken to landfills in other municipalities, but until March 2007, the city had two sanitary landfill sites and five undergoing maintenance, i.e. open but not receiving any waste material. Furthermore, during the 1970s, another eight landfill sites located in the municipality were opened, filled and then transformed into residential or commercial areas, or into public parks.^e

Considering the lack of studies evaluating the risks relating to such areas within the Brazilian context, the aim of the present study was to evaluate the association between living close to solid waste landfill sites and occurrences of cancer and congenital malformations among these populations.

METHODS

The 15 solid waste landfill sites within the municipality of São Paulo, SP, Southeastern Brazil, formed the subject of the analysis. All of these sites came into operation in the 1970s, except for one that came into operation in 1980.

The mortality database of the Mortality Information Improvement Program (PROAIM) of the municipality of São Paulo was used to select all the deaths that occurred between 1998 and 2002 for which the underlying cause, as classified in the tenth revision of the International Classification of Diseases (ICD-10), were as follows: liver cancer (C22 and C24) and bladder cancer (C67) for individuals aged 40 years and over; leukemia (C91 to C95) among individuals ≥ 15 years of age; leukemia among individuals < 15 years of age; and congenital malformations (Q00 to Q99) among children up to one year of age.

The addresses of the landfill sites and the individuals who died were geocoded and buffers of radius 2 km were created around each landfill site. The IBGE census tract map was overlain on this information, with the data from the 2000 census. Thus, for each buffer, new regional sections were defined using the census tract limits contained in these areas. For each of the 15 regions created, it was possible to determine the number of deaths according to the specific causes and to obtain census population data.

^b Instituto Brasileiro de Administração Municipal. Manual de gerenciamento integrado de resíduos sólidos. Rio de Janeiro; 2001.

^c Instituto Brasileiro de Geografia e Estatística. Pesquisa nacional de saneamento básico – 2000. Rio de Janeiro; 2002.

^d Companhia de Tecnologia e Saneamento Ambiental. Inventário estadual de resíduos sólidos domiciliares – 2008. São Paulo; 2008.

^e Silva FAN. Avaliação ambiental preliminar de antigas áreas de disposição de resíduos sólidos urbanos do município de São Paulo [master's dissertation]. São Paulo: Instituto de Geociências da USP; 2001.

The number of deaths expected was calculated according to sex and age group (using five-year intervals for ages up to 30 years and ten-year intervals for age groups after 30 years of age). The reference point taken was the municipality's experience of mortality for each outcome studied, and standardized mortality ratios (SMRs) were obtained for each locality.

The SMRs for each outcome were analyzed in Bayesian spatial models, using an adjacent spatial correlation matrix. This model made it possible to avoid the effect of localities with low numbers of inhabitants, adjust the estimates for spatial autocorrelation and find out whether the areas close to landfill sites presented higher risk of death for each outcome. The analyses were adjusted for socioeconomic condition, and a variable with information on the percentage of heads of households among the general population with monthly income less than one minimum salary was included in the model.

The model proposed was the following:

$$\log(O_i) = \log(E_i) + \alpha_0 + \alpha_i + \beta_1 \text{ (deactivated)} +$$

$$+ \beta_2 \text{ (maintenance)} + \beta_3 \text{ (in operation)} + \gamma (\% \text{income} < 1 \text{ min salary})$$

$$\text{SMR}_i = \exp(+ \alpha_0 + \alpha_i + \beta_1 \text{ (deactivated)} + \beta_2 \text{ (maintenance)} + \beta_3 \text{ (in operation)} + \gamma (\% \text{income} < 1 \text{ min salary})),$$

Where:

O_i is the number of deaths observed in relation to the cancer type of interest;

E_i is the number of deaths expected for the cancer type of interest;

α_0 is the parameter that represents the SMR of the standard population;

α_i is the increase in SMR for region i ;

β_1 is the effect on the SMR in areas close to deactivated open dumps;

β_2 is the effect on the SMR in areas close to open dumps undergoing maintenance;

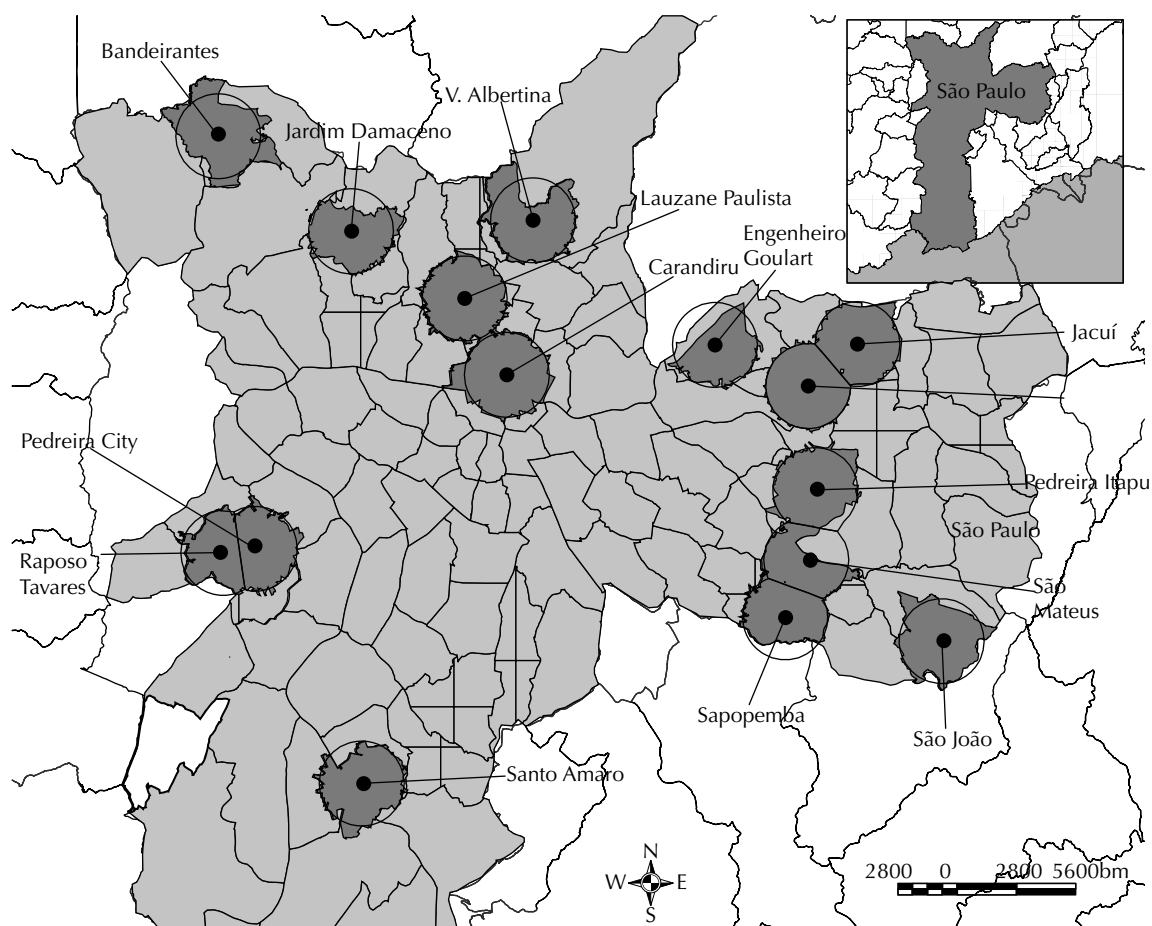


Figure 1. Locations of the solid waste landfill sites and areas of 2 km around them. City of São Paulo, Southeastern Brazil, 1998-2002.

β_3 is the effect on the SMR in areas close to open dumps that are in operation;

γ is the effect on the SMR when the percentage of heads of households with monthly income < 1 minimum salary varies between localities.

For the geocoding, the MapInfo Geographic Information System (GIS) was used (professional version 7.8; MapInfo Corporation, New York, NY, USA).

The models were adjusted using the WinBugs 14.0 software,^f which uses Markov chains and Monte Carlo simulations to estimate the variations in the SMRs within the spatial model.¹

This study was approved by the Ethics Committee for Research Project Analysis (CAPPesq) of the Clinical Board of the Faculdade de Medicina, Universidade de São Paulo (Protocol N 1009/02, on December 11, 2002).

RESULTS

The 15 landfill sites and their respective areas of 2 km radius are presented in Figure 1. In these regions, between 1998 and 2002, there were 351 deaths due to liver cancer, 224 due to leukemia among adults, 160 due to bladder cancer, 299 due to congenital malformation and 25 due to leukemia among children.

Table 1 presents the results from the Bayesian spatial model for each outcome. The SMRs did not indicate any excess risk for people living in areas close to the solid waste landfill sites in the municipality. The socio-economic variable (proportion of heads of households with monthly income < 1 minimum salary) was the only variable to show a statistically significant association, thus indicating that the risk of death due to these causes was more associated with low income than with proximity to the landfill sites.

The same analysis was performed for the different types of landfill site (deactivated, undergoing maintenance and in operation). In the areas surrounding the landfill sites that were in operation, there was a higher risk of bladder cancer, liver cancer and death due to congenital malformation. However, none of these results reached statistical significance.

In the analysis according to landfill site (Table 2), it was noted that the Carandiru and Pedreira City sites were the only ones to indicate higher risk for all the outcomes evaluated, although the results were statistically significant only for liver cancer in the area of the Carandiru landfill site. On the other hand, at other landfill sites

Table 1. Standardized mortality ratios (SMRs) for areas of 2 km around the solid waste landfill sites, according to selected causes of death and the situation of the landfill sites. City of São Paulo, Southeastern Brazil, 1998-2002.

Causes of death	Situation of landfill site	SMR	95% CI
Bladder cancer	All	0.98	0.79;1.21
	Deactivated	0.90	0.71;1.15
	Undergoing maintenance	0.98	0.64;1.52
Liver cancer	In operation	1.31	0.85;2.02
	All	1.00	0.86;1.16
	Deactivated	1.03	0.86;1.22
Leukemia in adults	Undergoing maintenance	0.84	0.61;1.16
	In operation	1.08	0.76;1.53
	All	0.92	0.77;1.10
Leukemia in children	Deactivated	0.94	0.78;1.13
	Undergoing maintenance	0.93	0.68;1.27
	In operation	0.87	0.59;1.28
Congenital malformations	All	0.84	0.54;1.31
	Deactivated	0.72	0.41;1.24
	Undergoing maintenance	0.98	0.45;2.12
	In operation	0.90	0.25;3.22
	All	0.86	0.72;1.03
	Deactivated	0.86	0.71;1.04
	Undergoing maintenance	0.73	0.53;1.01
	In operation	1.12	0.75;1.69

SMR: Standardized mortality ratio

and for several outcomes, the risk of death was lower in these areas than in the remainder of the municipality. It was also noted that the estimates for childhood leukemia were very imprecise, particularly in the areas of the Pedreira City and Santo Amaro landfill sites.

Maps with the smoothed SMRs estimated using the Bayesian model are presented in Figure 2. The highest SMR values were found in the more central regions of the municipality, rather than at the landfill sites, which were mostly in more peripheral areas.

DISCUSSION

The risk of death due to cancer or congenital malformations was no greater in the areas adjacent to the urban waste dumps than in the whole municipality of São

^f Bayesian inference Using Gibbs Sampling. WinBUGS 1.4.x. Cambridge; 2008 [cited 2009 Jul 22]. Available from: <http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/contents.shtml>

Table 2. Standardized mortality ratios (SMRs) for areas of 2 km around the solid waste landfill sites, per site, according to selected causes of death. City of São Paulo, Southeastern Brazil, 1998-2002.

Landfill site	Bladder cancer		Liver cancer		Adult leukemia		Childhood leukemia		Congenital malformations	
	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI
Bandeirantes	0.74	0.39;1.08	0.89	0.56;1.22	0.83	0.61;1.06	0.69	0.25;1.14	0.65	0.41;0.90
Jd. Damasceno	0.67	0.43;0.92	0.90	0.66;1.14	0.73	0.56;0.91	0.61	0.22;0.99	0.76	0.57;0.95
V. Albertina	1.09	0.69;1.49	0.99	0.70;1.28	1.02	0.78;1.25	1.01	0.39;1.63	0.83	0.52;1.13
Lauzane	0.94	0.69;1.20	1.07	0.86;1.28	1.04	0.84;1.23	1.06	0.46;1.66	1.00	0.75;1.24
Carandiru	1.13	0.81;1.45	1.30	1.00;1.60	1.18	0.92;1.43	1.16	0.48;1.85	1.19	0.84;1.54
Eng. Goulart	0.98	0.63;1.33	1.01	0.73;1.28	0.88	0.68;1.08	0.78	0.31;1.25	1.00	0.68;1.32
V. S. Francisco	0.97	0.71;1.24	1.05	0.84;1.26	0.93	0.75;1.11	0.84	0.37;1.30	1.03	0.79;1.27
Jacuí	0.89	0.62;1.17	1.13	0.86;1.39	0.89	0.70;1.07	0.75	0.31;1.19	0.86	0.65;1.07
Pedreira Itapuí	0.93	0.55;1.31	0.81	0.57;1.05	0.87	0.60;1.13	1.03	0.29;1.76	0.76	0.53;0.99
São Mateus	0.89	0.53;1.25	0.80	0.56;1.04	0.81	0.57;1.05	0.98	0.28;1.69	0.77	0.53;1.01
Sapopemba	0.78	0.45;1.11	0.71	0.49;0.94	0.80	0.56;1.04	1.00	0.29;1.71	0.65	0.45;0.84
São João	0.62	0.26;0.98	0.68	0.35;1.01	0.65	0.41;0.88	0.74	0.14;1.34	0.42	0.20;0.64
Raposo Tavares	0.75	0.46;1.05	0.97	0.69;1.26	0.94	0.72;1.15	0.83	0.33;1.32	0.91	0.63;1.19
Pedreira City	1.30	0.78;1.82	1.14	0.79;1.49	1.01	0.62;1.39	1.47	0.00;3.17	1.48	0.90;2.06
Santo Amaro	1.24	0.72;1.77	1.01	0.67;1.35	0.93	0.57;1.29	1.38	0.00;2.98	1.43	0.89;1.97

SMR: Standardized mortality ratio

Paulo. In a general manner, the risks encountered were in the opposite direction, i.e. less than 1.0 (one) and without statistical significance. Despite the higher risk for the outcomes evaluated at some of the landfill sites, the weak associations and imprecision of the estimates did not constitute sufficient evidence to establish a causal relationship.

Although there are studies in the literature that indicate higher risk of cancer among individuals living close to garbage landfill sites,^{9,10,15} the risks observed are generally of small magnitude and methodological problems make it difficult to ensure that other possible associated factors have been adequately dealt with.

The evidence for a possible association with outcomes like congenital malformations is somewhat more consistent.¹⁸ In the United Kingdom, where around 80% of the population lives within 2 km of a solid waste landfill site, two large population-based studies found excess numbers of congenital defects that could not be explained by other possible causes,^{5,6} even considering the influence of confounding variables and other methodological problems.

Nonetheless, it is important to discuss certain methodological limitations of the present study. One of these is the assumption that individuals living close to solid waste landfill sites are necessarily exposed to the toxic substances present in the site. However,

the gas emissions, soil and water table contamination and the length of time for which people had been living in their homes were not measured. There are uncertainties regarding the possible exposure routes: whether exposure occurs through contaminated water coming from the water table, through the air or through another mechanism. According to the World Health Organization (WHO),⁸ any potential exposure to contaminants present in solid waste dumps would probably be confined to a radius of 1 km, for aerial transmission, and 2 km, for waterborne transmission.

Nevertheless, the greatest challenge for epidemiological studies in this field is to be able to eliminate the effects of factors that might be related concomitantly to the outcomes evaluated and to the exposure, such as age, gender, race, socioeconomic condition, smoking, access to healthcare services and occupational history, among others. The use of SMRs and the inclusion of a variable relating to income in the present study had the aim of controlling for some of these factors. However, other potential confounding variables could not be controlled for, with the data available.

Furthermore, this study used mortality data, whereas the ideal would be to use incidence data relating to the outcomes studied. Cancer is a disease with a long induction period. Although the landfill sites in the municipality of São Paulo have existed since the 1970s, it is not known whether the individuals who died while

⁸ World Health Organization. European Centre for Environment and Health. Methods of assessing risk to health from exposure to hazards released from waste landfills. Report from a WHO Meeting Lodz, Poland, 10 – 12 April, 2000. Bilthoven; 2000.



Figure 2. Standardized mortality ratios for the areas of radius 2 km around the solid waste landfill sites and other districts. City of São Paulo, Southeastern Brazil, 1998-2002.

they were living close to these sites had been living in the same place for many years before developing the disease. This problem is relatively small when evaluating congenital malformations, since these imply an exposure period of up to nine months.

Although methodological problems made precise epidemiological evaluation difficult, in relation to the impact of this exposure on health, other evidence has justified the need for greater attention towards controlling and managing solid waste in urban areas. The diversity of potentially toxic substances present in urban garbage, the evidence of soil and groundwater contamination and the already reported effects of such exposure on populations living close to these areas need to be taken into consideration, not only in relation to planning and

implementing waste management policies, but also in relation to follow-ups among potentially exposed populations undertaken by the healthcare authorities.

Monitoring of these and other contaminated areas may benefit from geospatial evaluations like the one presented here. However, evaluations in greater detail, using different epidemiological approaches, may contribute towards deepening the knowledge on this topic. Such assessments may also provide support for designing and implementing measures aimed at minimizing the risks to health among the population, and contribute towards a better informed discussion among the different players who participate in the process of formulating public policies relating to urban waste, which is a problem with an important impact on public health.

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