Setting priorities for environmental sanitation interventions based on epidemiological criteria: A Brazilian study

Léo Heller, Enrico A. Colosimo and Carlos M. F. Antunes

ABSTRACT

The present study addresses the use of analytical epidemiologic approaches to subsidize the establishment of priorities in environmental sanitation interventions. An epidemiological investigation was carried out in 1993 in the urban area of Betim, a southeast Brazilian City of 160,000 inhabitants. The case-control 'inclusive' (or case-cohort) design, with a sample of 997 cases and 999 controls, was employed. Cases were defined as children of less than five years of age presenting diarrhoea episodes, while controls were randomly selected among children of the same age, living in the study area. After logistic regression adjustment, 11 of several exposure variables analysed were significantly associated with diarrhoea. Four different criteria, using as risk measures the relative risk, the attributable risk, the standardized coefficient of the logistic regression and the cost standardized coefficient, were used in order to define intervention priorities.

Key words | case-control, diarrhoea, health planning, hygiene practices, risk measures

Léo Heller (corresponding author)
Department of Sanitary and Environmental Engineering, School of Engineering,
Universidade Federal de Minas Gerais,
Av. Contorno, 842/701, 30.110-060,
Belo Horizonte,
Brazil
Tel: 0055-31-3238-1958
Fax: 0055-31-3238-1879
E-mail: *heller@desa.ufmg.br*

Enrico A. Colosimo
Department of Statistics,
Exact Sciences Institute, Universidade Federal de Minas Gerais,
Brazil

Carlos M. F. Antunes
Department of Parasitology,
Biological Sciences Institute, Universidade Federal de Minas Gerais,
Brazil

INTRODUCTION

Studies involving the relationship between environmental sanitation and health conditions have been receiving increasing attention in the literature since the beginning of the 1980s. Most of these studies, however, were primarily aimed at identifying health condition determinants (Birkhead & Vogt 1989) and evaluating sanitation programmes (Aziz *et al.* 1990*b*) Analytical epidemiologic studies, developed with the objective of subsidizing the establishment of priorities in environmental interventions, are rare in the literature. However, several authors have suggested this approach, as a logical basis for public health planning and action (Rothman & Greenland 1998).

The usefulness of epidemiological studies linking environmental sanitation conditions or programmes and health is controversial; nevertheless, its importance has expanded in the last two decades. In the middle of the 1970s, a publication by the World Bank (1976) discouraged the development of this type of investigation. In addition, Blum & Feachem (1983) published a review article, stating that most of the studies reported till that time had serious methodological limitations. In that same year, a workshop in this field was held in Bangladesh (Briscoe *et al.* 1986); at the conclusion of the discussions, the implementation of epidemiologic studies on water supply/sanitation exposures and health were again recommended. It was emphasized, however, that greater care regarding some important methodological aspects should be observed.

Since that time, several studies investigating the association between environmental sanitation and health have been developed. The following main features were observed in relation to 256 epidemiological studies published in the literature (Heller 1997):

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(a) Fifty-seven per cent (146) of the studies were developed in Asian (Magnani *et al.* 1993) or African (Manun'ebo *et al.* 1994) scenarios and this tendency has not changed over the last decades.
(b) Seventy-seven per cent (198) of the studies considered exposures related to water supply (Mertens *et al.* 1990) and 42% (107) exposures related to domestic wastewater disposal (Guerrant *et al.* 1983). Few investigations considered other environmental sanitation conditions, such as refuse disposal (Ekanem *et al.* 1991) (2%, 4), hygienic practices (Maung *et al.* 1992) (17%, 44) or drainage, vector presence (Blake *et al.* 1993) and other exposures (5%, 12). In most of the cases, only rural areas were investigated (Mertens *et al.* 1990).
(c) Forty-one per cent (105) of the studies adopted diarrhoea morbidity (Brüssow *et al.* 1993) as the health variable.
(d) Case-control designs have begun to be employed in the last decade. In the universe of studies under consideration, prospective (Aziz *et al.* 1990*a*) (25%, 64) and cross-sectional (Lonergan & Vansickle 1991) (21%, 53) were the most used designs.

Public health methods contribution in terms of decision-making on planning and setting priorities for public health actions or programmes is still a completely unexplored matter. Traditional risk measures, such as the relative risk and the attributable risk, are frequently proposed for this aim, but other approaches have been used, such as rapid assessment methods (Lerer 1999), multi-attribute rating technique (SMART) (Venter *et al.* 1998), disability adjusted life years (DALY) (Sayers & Fliender 1997), cost–benefit (Klevit *et al.* 1991) or cost-effectiveness (Venter *et al.* 1998).

Considering this diversity of possibilities in choosing a prioritization method, each of them with its own advantages and limitations, this paper presents the development and application of an epidemiological study oriented to a prioritization purpose. The authors understand that the development and testing of the several methods, with their respective critical evaluations, as presented here, will provide procedures improvement, by the public health and the environmental health sectors, achieving more justice and equity in policy application.

METHODS

Study area

The study was carried out in the urban area of Betim, a city with about 160,000 inhabitants. Betim is an industrial city, located in the Metropolitan Region of Belo Horizonte, the capital of Minas Gerais State, southeast Brazil, with a population of nearly 3.5 million inhabitants. A public concessionaire is responsible for the water supply and sanitation services. The other environmental sanitation services such as refuse collection and disposal, urban drainage and vectors control are directly conducted by the municipality.

Epidemiologic design

The case-cohort (or inclusive) design, a variant of the case-control method, in which the control group is representative of the source population, was adopted (Armenian & Gordis 1994; Rothman & Greenland 1998) in this study. A case was defined as child under five years old, living in Betim urban area, who has used a local health institution, public or private, reporting a diarrhoea episode. All local health institutions, including 15 public and 14 private health centres, were investigated; 997 cases were identified between 20 December 1993 and 4 April 1994.

A control was defined as a child under five years old, randomly selected from Betim urban area population. They were identified through a random selection of houses, taken from a register utilized by the municipality for property taxing. In field conditions, when the selected house did not have a resident child under five years old, displacement to the left house was adopted. For other situations, when the selection was not possible, other standardized criteria were adopted. The 999 selected controls were interviewed from 23 November 1993 to 22 April 1994; the majority of the data collection was carried out before 18 December 1993.

The sample size determination was based on methods for independent case-control studies (Schlesselman 1982), using multicategorical exposures (Briscoe *et al.* 1985).

The mother or a person responsible for the child was interviewed by a team of ten trained interviewers recruited among the local residents. All the interviewers were familiarized with this kind of activity. Interviewing in the same region as the interviewer's residence was avoided. Double-blind interviews were planned, but in some situations, masking the case or control status was not possible. Information from the questionnaires, after coding, was introduced in a database, developed with the software MS-Access for Windows (Jennings & Person 1993). The data set was double-checked. A more detailed description of the adopted procedures has been published elsewhere (Heller *et al.* 2003).

Exposure variables

Besides several potential confounding factors, 36 questions related to environmental exposure variables were included in the questionnaire, grouped into the following categories: (1) water supply; (2) individual hygienic practices; (3) wastewater disposal; (4) existence of superficial streams near the residence; (5) domestic refuse storage and disposal; (6) rainwater flooding and pounding; and (7) vectors presence.

Data analysis

The data analysis was achieved through a sequence of steps, when several associations and confounding factors had progressively been identified. First, the data set was organized using the software MS-Excel 4 for Windows (The Cobb Group 1993) and second, it was statistically analysed using the software SYSTAT (Wilkinson *et al.* 1992), EPIINFO (Dean *et al.* 1990) and MULTLR (Campos Filho & Franco 1988). The statistical analysis sequence followed four steps: (1) frequency distribution and a two-sample test; (2) univariate analysis (Schlesselman 1982), including the RR point estimate and its confidence interval (Cornfield method), trend analysis (Mantel method) and the AR point estimate and its confidence interval; (3) bivariate analysis, with inspection of potential confounders (Mantel-Haenszel method (Mantel & Haenszel 1959)) and identification of modifier effects; and finally (4) multivariate analysis, using a logistic regression model.

The logistic regression analysis was accomplished through the following steps (Hosmer & Lemeshow 1989): (1) preliminary selection of variables to be included in the model, from the univariate analysis, using $p < 0.25$ (Mickey & Greenland 1989); (2) construction of independent logistic models, using eight different homogeneous subgroups (familiar structure, socio-economic variables, hygienic practices, water supply, sanitation, urban refuse disposal, drainage and vectors presence); variables were discarded from these subgroups when $p > 0.15$; (3) construction of the final model by grouping the independent subgroup models, maintaining only variables with $p < 0.05$; and (4) multiplicative effect modification analysis. Variables known to be associated with diarrhoea were kept in the models throughout the analysis, even when they did not reached the established significance levels.

For the priorities setting discussion, besides the traditional risk measures as described, two other measures were used (Schlesselman 1982): (1) the standardized coefficient of the logistic regression, determined by (Truett *et al.* 1967):

$$\hat{\beta}_i' = \hat{\beta}_i\sqrt{\mathrm{var}(x_i)}$$

where i represents the i-th coefficient of the logistic model; and (2) the reduction of the logit of risk in terms of a fixed cost (Snedecor & Cochran 1989). This reduction is evaluated from the magnitude of the changes $\Delta x_1, \ldots \Delta x_p$ that can be imposed in the exposures by a given expenditure of resources. The measure is then obtained by ranking the exposures by the size of $\Delta x_i \hat{\beta}_i$. This measure was adapted for the binary exposures of the study. A cost research of typical Brazilian public services was developed and a value c in the country currency (Real) was obtained that corresponds to changing each exposure from the risk condition to the non-risk one. A similar measure was defined by $c_i/\ln(\hat{\beta}_i)\times$ $(= c_i/RR_i)$ and the ranks are obtained in an increasing order. Finally, a combination of the four criteria was obtained by averaging a standard scale of the four ranks.

RESULTS

About 29% of the cases were lost before interview, mainly due to unknown addresses, and were replaced by other identified cases as established in the previous section. The controls were uniformly distributed along the 66 regions of Betim, with no significant difference in the proportion of selected children per occupied houses ($p > 0.050$ in the two-sample test).

Table 1 | Non-adjusted relative risk for the main exposures, as dichotomous variables (997 cases, 999 controls)

Variable	Comparison	RR (95% CI)
Fruits and greens hygiene	Other care × disinfection	4.75 (2.84–8.05)
Refrigerator ownership	No × yes	3.39 (2.71–4.24)
Domestic water reservoir existence	No × yes	3.29 (2.62–4.13)
Method of water withdrawal from dug well	Manual × pump	3.00 (0.74–13.16)
Feces disposal from swaddle	Other × toilet/latrine	2.94 (2.19–3.94)
Water supply source	Other source × public network system	2.78 (1.51–5.18)
Superficial presence of wastewater in street	Yes × no	2.74 (2.27–3.32)
Refuse storage	Other × refuse package	2.51 (2.05–3.06)
Hand hygiene after defecation	Never/low frequency × frequent	2.34 (1.84–3.06)
Bathroom existence	No/outside × one or more	2.15 (1.69–2.73)
Flooding in lot	Yes × no	2.11 (1.75–2.56)
Rats presence	> Once a semester × < once a year	2.08 (1.72–2.52)
Refuse disposal	Other × public collection	1.99 (1.61–2.48)
Wastewater disposal	Other × public collection system	1.97 (1.63–2.37)
Hand hygiene before eating	Never/low frequency × frequent	1.92 (1.48–2.50)
Cockroaches presence	>3 months a year × < one month a year	1.74 (1.45–2.09)
Well water quality complaint	Yes × no	1.67 (0.35–7.22)
Refuse collection frequency	2 times a week × 3 times a week	1.66 (1.30–2.11)
Flies presence	>3 months a year × < 1 month a year	1.59 (1.29–1.96)
Drinking water care	No × yes	1.55 (1.33–2.14)
Domestic reservoir coverage	No × yes	1.52 (1.00–2.31)
Mosquitoes presence	All time × < 6 months a year	1.48 (1.23–1.78)
Pooling in lot	Yes × no	1.46 (1.19–1.80)
Chlorination in dug well	No × yes	1.29 (0.18–6.94)
Public network water shortage	Yes × no	1.24 (1.03–1.49)
Contact with near stream water	Yes × no	1.22 (0.54–2.79)
Domestic reservoir cleaning	Never × sometimes	1.19 (0.88–1.61)

Table 1 | (*continued*)

Variable	Comparison	RR (95% CI)
Near stream existence	Yes × no	1.14 (0.94–1.37)
Wastewater network blockage	Yes × no	1.11 (0.75–1.65)
Public network water complaint	Yes × no	1.03 (0.66–1.61)
Dug well coverage	No/inadequate × adequate	0.96 (0.24–4.36)
Fruits and greens hygiene	No × yes	0.64 (0.30–1.36)

In Table 1, relative risk estimates for the main exposures, converted into dichotomous variables, as determined in the univariate analysis and its respective 95% confidence intervals, are presented.

After the multivariate analysis, several of the variables significantly associated with diarrhoea, based on the crude relative risk, were removed from the model. An association among some environmental sanitation and hygiene variables and the presence of several confounding factors can be detected by comparing the values in Table 1 with those in the multivariate analysis presented in Table 2. Table 2 describes the remaining variables in logistic regression, with their adjusted relative risk and confidence interval. More details of the case-cohort study main results were presented elsewhere (Heller *et al.* 2003).

Table 3 presents, using the remaining variables defined in Table 2, the values of the four risk measures adopted for the priorities setting analysis. Table 3 also shows the combined criteria. For better visualization, the combined criteria related to a standard scale are presented graphically in Figure 1.

DISCUSSION

Among several exposures and confounding factors under study, after the adjustment by logistic regression, 16 dichotomous comparisons showed significant values for the relative risk, up to 2.87 (point estimate), as presented in Table 2. This fact points out that an important impact on the health status of Betim's children can be achieved by the implementation of environmental sanitation measures and hygiene education actions.

Discussion of priorities in ordering interventions based on epidemiologic indicators, aiming to optimize resources application efficacy, requires a critical analysis of the concepts involving risk measures. The RR, a ratio of incidence rates (exposed/non-exposed) reflects the strength of the association exposure–disease. In this investigation, it indicates the average risk of diarrhoea associated with a given exposure. The AR reflects the amount of disease which can be prevented in the population if a risk factor is eliminated. In this investigation, it indicates the proportion of diarrhoea that would be prevented if a given exposure were removed. Comparing the importance of these measures, the use of AR favours interventions over exposures that have higher frequencies in the population, hence those widest and probably more expensive interventions. The RR, in contrast, shows an individual comparison, avoiding the above populational distortion, although all the interventions do not have the same unitary cost.

The third criterion standardizes relative risk values, according to variances of observations, setting these values on a similar comparison basis. The fourth criterion introduces, in association with the health risk factor, the cost variable, which is extremely important in this kind of analysis, where a public decision of prioritization is discussed.

In view of such considerations, giving least importance to attributable risk and favouring the two standardized coefficients, without ignoring the traditional relative risk, it seems to be a consistent methodology. Besides this, the priority setting of interventions has to consider the nature of

Table 2 | Variables remaining in the logistic model: Relative risk for diarrhoea and respective confidence interval, without and with effect modification

Variable	Comparison	$RR_{Adjusted}$ (model without effect modification)	$RR_{Adjusted}$ (model with effect modification)
(1) Fruits and greens hygiene	No × yes	2.87 (1.61–5.10)	2.79 (1.57–4.96)
(2) Mother religion	No × yes	2.58 (1.18–5.65)	2.68 (1.21–5.92)
(3) Superficial presence of wastewater in street	Yes × no	2.38 (1.87–3.03)	1.47 (1.00–2.16)
(4) Refuse storage	Other × refuse package/no storage	1.97 (1.55–2.50)	1.46 (1.08–1.97)
(5) Domestic reservoir	No storage × covered and cleaning reservoir	1.91 (1.37–2.67)	1.43 (0.88–2.35)
(6) Domestic reservoir	Vessel storage × covered and cleaning reservoir	1.91 (1.01–3.60)	1.62 (0.58–4.50)
(7) Child age	Continuous variable	1.81 (1.63–2.02)	1.83 (1.64–2.03)
(8) Feces disposal from swaddle	No swaddle use × toilet/latrine disposal	1.65 (1.21–2.24)	1.63 (1.20–2.22)
(9) Refuse disposal	Vacant lot/stream disposal × frequent public collection	1.61 (1.11–2.34)	1.57 (1.07–2.29)
(10) Children number	Continuous variable	1.58 (1.28–1.95)	1.61 (1.30–1.99)
(11) Near stream existence	No × yes	1.57 (1.22–2.01)	1.56 (1.21–2.01)
(12) Feces disposal from swaddle	Other × toilet/latrine disposal	1.50 (1.04–2.19)	1.45 (0.99–2.12)
(13) Refrigerator ownership	No × yes	1.41 (1.12–1.76)	1.38 (1.03–1.86)
(14) Cockroaches presence	>3 months a year × < 1 month a year	1.40 (1.12–1.76)	0.93 (0.59–1.47)
(15) Flooding in lot	Yes × no	1.39 (1.09–1.76)	1.40 (1.10–1.79)
(16) Mosquitoes presence	All time × < 6 months a year	1.37 (1.08–1.73)	1.05 (0.75–1.48)
(17) Refuse collection frequency	2 times a week × 3 times a week	1.33 (0.99–1.79)	1.32 (0.98–1.79)
(18) Domestic reservoir	Covered and uncleaning × covered and cleaning	1.07 (0.82–1.40)	1.19 (0.81–1.76)
(19) Domestic reservoir	Uncovered and cleaning × covered and cleaning	1.02 (0.56–1.88)	0.35 (0.12–1.04)
(20) Domestic reservoir	Uncovered and uncleaning × covered and cleaning	0.94 (0.40–2.20)	0.52 (0.12–2.18)

Table 2 | (continued)

Variable	Comparison	$RR_{Adjusted}$ (model without effect modification)	$RR_{Adjusted}$ (model with effect modification)
Interaction terms			
(3) * (4)	–	–	2.17
(5) * (14)	–	–	1.71
(6) * (14)	–	–	1.30
(18) * (14)	–	–	0.80
(19) * (14)	–	–	5.60
(20) * (14)	–	–	2.89
(14) * (16)	–	–	1.67

interventions. In this perspective, several of the significant exposures correspond to educational interventions, instead of physical ones. And, based on the principle that health (including hygiene and environmental) education must constitute a systemic approach, where a set of orientations should be done, these interventions can be grouped as a wide educational process.

Another approach that seemed to be valid in this study is the integration of the four criteria as synthesis indexes. The combination of the first two criteria resulted in similar ranking order. Although this integration seems to over represent the RR value, in view of its participation in the computation of the four proposed risk measures, this could be accepted due to the conceptual importance of RR. However the fact that RR is present also in the numerator and in the denominator of the risk measures expressions attenuates the presumed over representation.

Based on the overall results, the study suggests the following priority order of interventions:

(1) Personal and domestic hygiene (can also be associated with vectors control, disposal of feces from swaddle and food conservation).
(2) Adequate refuse management (can also be associated with cockroaches and fly control).
(3) Collective wastewater disposal.
(4) Adequate storage of water for consumption.
(5) Elimination of surface flooding.

In the specific case of Betim and, with appropriate care, in similar urban cities, this order of priorities can be seen as a reference for health and environmental public policies. It avoids in this way subjective criteria. Measures related to hygiene are present in all criteria and consequently in the synthesis criterion, confirming the emphasis received by personal and domestic hygiene in the literature. They point out its public health impact (Alam *et al.* 1989), the need to improve its practical application (Pinfold *et al.* 1991) and its theoretical and policy gaps (Almedon & Curtis 1995).

Possible limitations of the present findings can be analysed through a number of aspects. Loss of cases was 29% of the total selected children. However, no evidence of relationship between losses and exposures seems to occur. A chi-square test for the case losses proportion in each of

Table 3 | Interventions related to the variables remaining in the logistic model: Risk measures

	Relative risk			Attributable risk (%)			Standardized coefficient of the logistic regression			Cost index: value (in Real)/RR			Final ranking	
Intervention	**Value**	**Order**	**Adj.**	**Value**	**Order**	**Adj.**	**Value**	**Order**	**Adj.**	**Value**	**Order**	**Adj.**	**By average adj.**	**By average order**
Fruits and greens disinfection	2.87	1	100	77.32	1	100	0.2431	4	35	4.38	1	100	1	1
Wastewater removal from street	2.38	2	67	33.79	3	39	0.4269	1	100	275.09	10	14	3	3
Adequate domestic storage of refuse	1.97	3	40	47.06	2	58	0.3291	2	65	7.82	5	99	2	2
Elimination of vessel water storage	1.91	4	36	18.79	9	18	0.1456	11	0	223.21	7	30	9	9
Provision of domestic water reservoir (when water is supplied directly from street)	1.91	4	36	5.56	11	0	0.2623	3	41	223.21	7	30	8	5
Elimination of refuse disposal in vacant lots and streams	1.61	6	16	13.71	10	11	0.1643	6	7	18.63	6	95	5	6
Orientation to feces from swaddle disposal in toilet or latrine	1.50	7	9	18.84	8	19	0.1458	10	0	7.33	4	99	6	7
Incentive to use of refrigerator	1.41	8	3	26.19	5	29	0.1490	9	1	319.15	11	0	11	11
Cockroaches presence reduction (from minimum 3 months/year to maximum 1 month/year)	1.40	9	2	27.02	4	30	0.1680	5	8	5.17	2	100	4	4
Elimination of flooding in lot	1.39	10	1	23.20	6	25	0.1568	7	4	260.43	9	19	10	10
Flies presence reduction (from all year to maximum 6 month/year)	1.37	11	0	21.24	7	22	0.1515	8	2	5.28	3	100	7	7

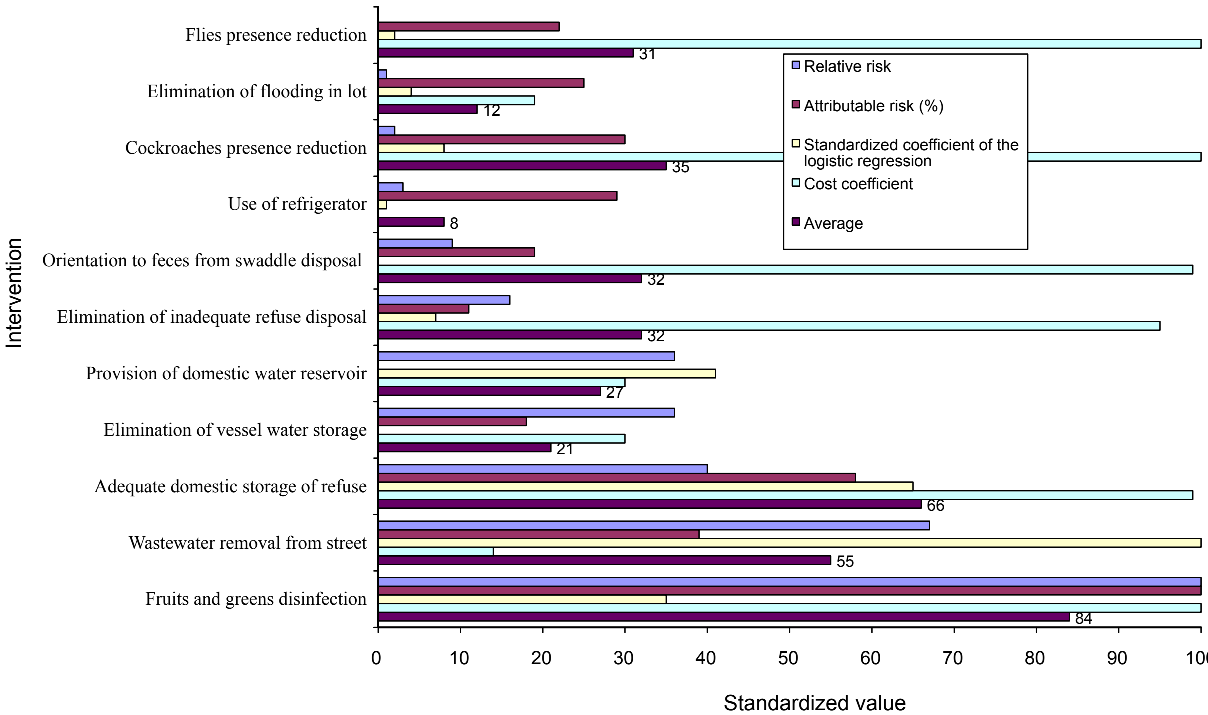

Figure 1 | Standardized values of the prioritization criteria.

the 29 health institutions shows that in only two of them was the proportion of losses statistically different from the mean. In one of them, the institution is extremely small (1.80% of total cases) and the losses were higher than the mean. The other one is also a small institution (4.10% of total cases) whose catchment area embraces the whole study area.

According to the results of a reliability test (Heller *et al.* 2003), variables related to public environmental sanitation conditions and house characterization – such as reservoir existence and conditions – are more reliable, since direct observation for validation of the answers was carried out. As a consequence, information related to personal and domestic habits are less reliable.

Generalization of this methodology for priority setting based on epidemiologic criteria seems to be possible for urban areas with analogous size and public services. The epidemiological design – case-cohort – proved to be valid, since some potential bias on the control group selection, frequent in traditional case-control studies, can be avoided. However, some simplifications can be visualized, such as smaller sample size, investigation of a smaller number of confounding variables and the dichotomization of variables during the statistical analysis.

It is important to point out that priority definition of environmental sanitation interventions constitutes a complex process, where several dimensions and constraints should be taken into account. Social, political, economic, urban structure and personal comfort are also important dimensions to consider in this decision. Undoubtedly, in this process, the public health dimension, especially in developing countries, has to play a determining role.

Finally, a decision tool presented here should be viewed as a support to the decision-making processes, and not as the unique instrument. Especially in democratic societies of developing countries, such instruments can be a powerful support for discussions in popular participation forums, charged with the formulation of public health policies.

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