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Assessment of Environmental Health Children's Population Living in Environmental Injustice Scenarios

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Abstract We conducted a cross sectional study, involving 145 children randomly selected from three different socioeconomic locations. We selected social, environment and health indicators and measured the prevalence and prevalence odds ratios. Children from the brick producing site (segregation index 5), are exposed to high levels of multiple toxic agents, and showed the highest morbidity rates and malnutrition, anemia, dental fluorosis, and the lowest IQ, followed by children from municipal garbage dump (segregation index 4), where we detected the highest prevalence of dermatological and enteric diseases. Children from the Central Zone (segregation index 2) showed the lowest rates of malnutrition and higher IQ than the other two groups. A unified vision of social, health and environmental indicators opens the possibility of novel intervention programs and a legal framework that specifically protect children against environmental exposures.

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Introduction

Environmental injustice involves a series of concepts concerned with the unequal distribution of social and environmental risk factors that affect, in a simultaneous and unfavorable way, both the quality of life and health of vulnerable populations. The concept of environmental justice—or distributive and procedural justice with respect to environmental goods—has a long history, rooted in the teachings of major religions and the practices of ancient societies. Environmental injustice concerns have increasingly focused on racial "minorities" and ethnic groups, migrant workers, women and children-specific issues [1–3].

Research conducted in low income populations in the U.S., primarily Afro-American and indigenous communities, has shown a high rates of asthma associated with exposure to breathable particles, inadequate housing and lack of sanitation infrastructure [4, 5]. The use of firewood for cooking may result in greater incidence of respiratory diseases among adult women and young children living in predominantly indigenous rural zones in Mexico [6].

The risk of pulmonary cancer was higher among adults living in economically deprived areas with high levels of air pollution when compared with the general population [7–12].

There is empirical evidence concerning children's health risk reflecting environmental injustice. Blood lead levels in children living near mining sites accurately reflect the presence of this metal in soil and dust of homes, and have been inversely associated with the poor nutrition and

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intellectual quotient (IQ) [13, 14]. Low standards of water supply, sanitation and hygiene conditions are statistically associated with excess risk of enteric diseases among children from periurban settlements in Mexico City [15]. Conventional approaches, however, may substantially reduce this evidence into limited interpretations, restricting the possibility of implementing programs and effective broad scope interventions.

The objective of this investigation was to identify children's health risk reflecting environmental injustice, while following an analysis that will provide multidimensional exposure scenarios, as well as the necessary basis for feasible interventions.

Population and Methods

This project fulfilled the IRB bioethics requirements (record commission 0005/2009).

We conducted a cross sectional study, involving children living in three socioeconomically different locations in the City of San Luis Potosi, Mexico.

Study Sites

The inclusion criteria were: (a) levels of segregation and poverty, according to the Index developed by the National Population Council [16]. This Index has 5 categories (level 1-very low segregation, while level 5 corresponds to communities with very high segregation); (b) type and sources of contamination; and (c) level of aggregation per the basic geostatistical area (AGEB). The following sites were included in this investigation:

1. Brick producing site, which includes 148 small-scale traditional brick kilns industries, producing 3 million bricks per year. Approximately 500 families' income depends on this activity, which involves considerable child labor. A total of 2,135 inhabitants live in this site, and 23% of them correspond to children between 3 and 12 years of age. The segregation level is very high i.e., 5 [16]. Open-topped adobe kilns are mostly fired with sawdust (42%), sawdust/wood mixture (15%), garbage with plastics (30%) and, in a lesser proportion, wood scraps (6%), used tires (1.6%), and different lubricating oils (5.4%). The burning of these fuels liberates into the atmosphere carbon monoxide, sulphur dioxide, polycyclic aromatic hydrocarbons and lead, among other pollutants [17].
2. The municipal garbage dump is located at the outskirts of the city. A total of 1,055 inhabitants live in this site, and 26% of them are children aged between 3 and 12 years, and the segregation index is 4 [16]. This site receives between 800 and 850 tons of municipal garbage and industrial wastes per day, which covers a surface of 6 hectares, 24 meters high, and a series of chimneys for the control and elimination of biogas. This process, however, does not have systems for monitoring, controlling, recovering and neutralizing lixiviates. The contaminants emitted into the environment include: carbon monoxide and dioxide, sulphur dioxide, nitrogen oxide, methane, arsenic, heavy metals (lead, cadmium, mercury) and aromatic polycyclic hydrocarbons, among other pollutants [18].
3. The central zone is located at one side of historical downtown area, involving 47 neighborhoods. The segregation index is 2 and the population is 3,640 inhabitants, of which 16% are children between ages 3 and 12 [16]. The main source of environmental pollution comes from motor vehicle traffic.

Sample Selection

The sampling unit was the child. We identified a total of 584, 491 and 274 children between 3 and 12 years of age in central zone (CZ), brick producing zone (BPZ) and municipal garbage dump (MGD), respectively. In each study site we recruited children who met the following inclusion criteria: ages between 3 and 12 years, time of residence at the selected site since birth, location of the household within the concerned geographic area, and signed letter of informed consent obtained from parents or guardian, grouping a total of 335 potentially eligible children (CZ = 84; BPZ = 124; MGD = 126). From these subpopulations we performed a systematic random sampling with replacement, choosing between 40 and 50% of the potential study population (MGD = 40%; BPZ = 41%; CZ = 52%) [19]. The final size of the population sample included a total of 145 children, 50 from the municipal garbage dump, 51 from the brick producing zone and 44 from the central zone. We compared children who participated in the current study with those not participated (despite met the inclusion criteria), and no significant differences were found for child's age, sex, mother's education, income and segregation. Sample characteristics for the sociodemographic variables are presented in Table 1.

Data Collection

We used previously validated and standardized questionnaires, and conducted anthropometry test. We assessed the nutritional status by measuring weight, height and age, and calculated the Z scores using the CDC/NCSH population as a reference; children outside the range, with Z ± 1.88 (percentiles 3 and 95) were considered to be undernourished

Table 1 Sociodemographic characteristics of children participating from the central zone (CZ), municipal garbage dump (MGD) and brick producing zone (BPZ)

Sociodemographic characteristics	CZ (n = 44)	MGD (n = 50)	BPZ (n = 51)
Female (%)	45	36	45
Male (%)	54	64	55
Child age (years)	7.4 ± 2.3	6.8 ± 1.9	7.1 ± 2.0
Weight (kg)	30.6 ± 12.4	23.9 ± 8.5	24.4 ± 7.8
Height (cm)	126.0 ± 14.5	117.8 ± 11.5	119.1 ± 12.0
Mother's education (years)	11.0 ± 3.6	6.4 ± 1.8	5.6 ± 1.9
Segregation (index)	Low (2)	High (4)	Very high (5)

Data are mean ± SD, except as noted

(chronic malnutrition, acute malnutrition, low weight) (<−1.88; level II) or overweight (>+1.88) [20]. We also conducted neuropsychological evaluations, using both the Wechsler-Wisc-RM child intelligence scale (for children aged 6 and 12 years) and the Wechsler-Wipsy tests (for children between 3 and 5 years of age), standardized and validated for Mexican children [21]. The Intellectual Quotient (IQ) was considered normal if the child scored 90–110 or below normal when the score was <90. Both tests were applied and interpreted by experimented psychologists from the School of Psychology (UASLP). We also gathered a series of social, environmental and health variables, based on available evidence concerning their potential or actual role as risk factor [22–25]. Description of the analytical and clinical laboratory methods used to obtain the information of the exposure indicators group selected are showed in Table 2.

Morbidity data were obtained from the child's clinical record.

Data Analysis

Prevalence and Prevalence Odds Ratios (POR) (95% confidence intervals) were calculated for health, social and

Table 2 Description of the analytical and clinical laboratory methods used to obtain the information of the selected and evaluated exposure indicators group

Indicator	Clinical analysis[a]	Toxicological analysis[b]	Description
Anemia	Haematic Biometry	–	5 ml of blood were taken in tubes with EDTA. The primary and secondary eritrocitary index was obtained, comparing with normal ranks according to age and sex [29].
Acute respiratory infections	Pharyngeal exudate	–	Samples with sterile hyssops were taken. They were transported in Stuart media and inoculated in gelosa blood sheep (5%) and gelosa chocolate. They were incubated during 18–24 h in CO_2 atmosphere (5–10%) to 35°C. The identification was realized according to international microbiological norms [30].
Intestinal parasites	Coproparasitoscopic analysis	–	A daily sample was taken during three consecutive days and it was placed in a sterile bottle. The technique of concentration and sedimentation by flotation of Faust et al. [30] was used.
Lead	–	Absorption atomic spectrometry (AAS)	100 µl of blood were taken and they were homogenized with a triton modifier solution. The quantification was performed by AAS with graphite furnace (Perkin-Elmer 3110), following the Subramanian's method [31]. Internal control qualities were used (WSLHPT: 04PB23, 04PB24, 04PB25).
Fluoride	–	Potenciometric method	100 ml of urine were collected in sterile bottles. The determination was realized according to the potenciometric method with electrode of ion selective fluoride. We used a quality internal standard (Fluoride freeze-dried urine 2671). We followed the NIOSH methodology [32].
Polycyclic aromatic hydrocarbons (PAH)	–	High performance liquid chromatography (HPLC)	100 ml of urine were collected in sterile bottles. 1-OH-Pirene metabolite was used as exposure indicator. Its extraction and quantification was realized following the methodology of Kuusimäki et al. [33]. HPLC with fluorescence detector was used. Certificated quality internal standards were used (1-OH-Pireno, Aldrich 98% pure).
Persistent organic pollutants (POP)	–	Gas chromatography mass spectrometry (GC–MS)	10 ml of blood were taken and 4 ml of plasma were obtained. The extraction and quantification of compounds were realized according to the methodology of Muckle [34]. Certificated quality internal standards were used.

[a] Analyses conducted at the Laboratory of Clinical Analyses—"Dr. Ignacio Morones Prieto" Central Hospital in San Luis Potosí, S.L.P.

[b] Analyses conducted at the Environmental Toxicology Laboratory of the Autonomous University of the San Luis Potosí (UASLP)—Faculty of Medicine

environmental indicators, while applying the Mantel-Haezsel Chi^2 statistical significance test. Analysis was conducted using the SPSS 12.0 for Windows (Copyright© SPSS Inc., 2003) and EpiInfo™ 3.3.2 programs (Database and statistics software for public health professionals, CDC 2004).

Results

The prevalence of social, environmental and health indicators assessed in this study are shown in Table 3. The lowest segregation index site (CZ) was taken as the reference site (POR = 1.0). Results of the prevalence odds ratio (POR) are shown in Tables 4, 5, 6. The analysis of these results was focused only on indicators that showed significant difference between the reference site (CZ) and the other two sites with high (MGD) and very high (BPZ) segregation index, therefore indicators of respiratory disease and access to health services were excluded. Likewise, the child labor indicator was not included in these results because the reference site (CZ) showed zero positive cases, so it was not possible to estimate the POR. The difference between sites was quiet evident. Finally, positive cases of both indicators of firewood use and burning of solid waste were added to facilitate the calculation of the POR.

Children living in the brick producing site (segregation index 5) showed the highest prevalence of dental fluorosis, anemia and malnutrition (Table 4). Chronic malnutrition (stunted) was detected in 22% of them; acute malnutrition

Table 3 Results of the obtained prevalence for all social, environmental and health indicators analyzed in the three study sites

Dimensions/groups of indicators	CZ			MGD			BPZ		
	n	Cases	Prev. %	n	Cases	Prev. %	n	Cases	Prev. %
Health dimension									
Morbidity (M)									
Respiratory	39	35	90.0	41	33	80.0	44	39	89.0
Dermatologic	39	8	21.0	41	15	37.0	44	13	30.0
Gastrointestinal	39	5	13.0	41	10	24.0	44	6	14.0
Diarrheas	39	5	13.0	41	11	27.0	44	8	18.0
Dental fluorosis	39	20	51.0	41	22	54.0	44	31	70.0
Malnutrition	44	8	18.0	50	18	36.0	49	25	51.0
Anemia	43	5	12.0	51	10	20.0	47	11	23.0
Direct health determinants (DHD)									
Respiratory Infections	43	16	37.0	48	30	62.0	39	25	64.0
Parasites	28	7	25.0	34	20	59.0	38	12	32.0
Lead (% > 5.0 μg/dl)	43	12	28.0	50	47	94.0	50	49	98.0
Fluoride (% > 1.5 mg/l)	43	22	52.0	47	37	74.0	43	38	84.0
PAH (% > DL = 0.1 ng/l)	39	29	74.0	32	25	78.0	30	26	87.0
POP (% > DL = 0.3 ng/l)	35	14	42.0	48	26	53.0	46	27	58.0
Low intellectual quotient	29	1	3.0	42	26	62.0	45	26	58.0
Social dimension									
Social determinants (SD)									
Low education	70	17	24.0	75	52	69.0	68	52	76.0
Low income	50	28	56.0	34	29	85.0	31	19	61.0
Overcrowding	41	10	24.0	42	30	71.0	43	29	67.0
Infrastructure of sanitary services	42	3	7.0	44	27	61.0	43	14	32.0
Child labor	41	0	0.0	37	21	57.0	39	13	33.0
No access to health services	42	16	38.0	43	17	40.0	42	18	43.0
Environmental dimension									
Environmental determinants (ED)									
Firewood use	42	0	0.0	43	33	77.0	43	8	19.0
Burning of solid waste	39	2	5.0	36	26	72.0	38	27	71.0
Presence of insects	39	21	54.0	41	31	76.0	41	26	63.0
Pesticide use	36	23	64.0	39	32	82.0	44	33	75.0

Table 4 Results of prevalence odds ratios (POR) for the morbidity group indicators (M) in central zone (CZ), brick producing zone (BPZ) and municipal garbage dump (MGD)

Morbidity (M)	Study sites (segregation index)	POR	CL 95	Chi^2 Mantel-Haezsel	*P* value
Dermatologic	CZ(2)	1.00			
	BPZ (5)	1.61	(0.81–3.23)	2.13	0.1442
	MGD (4)	2.21	(1.13–4.36)	6.22	0.0126
Gastrointestinal	CZ (2)	1.00			
	BPZ (5)	1.09	(0.45–2.64)	0.04	0.8360
	MGD (4)	2.11	(0.95–4.74)	4.01	0.0451
Diarrheas	CZ (2)	1.00			
	BPZ (5)	1.47	(0.64–3.42)	0.95	0.3280
	MGD (4)	2.48	(1.13–5.49)	6.13	0.0133
Dental fluorosis	CZ (2)	1.00			
	MGD (4)	1.13	(0.62–2.04)	0.18	0.6709
	BPZ (5)	2.24	(1.21–4.18)	7.55	0.0065
Malnutrition	CZ (2)	1.00			
	MGD (4)	2.56	(1.27–5.20)	8.22	0.0041
	BPZ (5)	4.74	(2.38–9.52)	24.10	<0.0001
Anemia	CZ (2)	1.00			
	MGD (4)	1.83	(0.79–4.28)	2.38	0.1228
	BPZ (5)	2.19	(0.96–5.04)	4.19	0.0406

(low weight for age) in 16%, and overweight in 8%, followed by children from municipal garbage dump (18% chronic; 6% acute; and 10% overweight). The highest prevalence of dermatological and enteric diseases –gastrointestinal and diarrheas- was detected among children from the municipal garbage dump (segregation index 4). Children from the central zone showed the lowest rates of malnutrition (2% chronic; 2% acute; and 14% overweight).

The highest prevalence of intestinal parasitic diseases was detected among children from the municipal garbage dump (Table 5); children from the brick producing site had a higher prevalence of both upper respiratory infections and exposure to environmental toxins than children from the other two groups. In addition, children from municipal garbage dump and brick producing site showed an IQ below the threshold considered as normal; their average IQ scores were 87 and 86 (borderline), respectively. By contrast, children from the Central Zone showed an average IQ of 99 (normal). As Table 4 shows, the risk of low IQ was 40 or 50 times higher among children from municipal garbage dump and brick producing site when compared with children from the central zone.

Households from the municipal garbage dump site showed the poorest income, overcrowded housing and weaker sanitation infrastructure. The lowest levels of education were recorded in households from the brick producing site (Table 6). Practically all indicators showed a gradient of prevalence and risk, reflecting the communities' segregation levels. According to this, municipal garbage dump showed the highest prevalence of burning garbage, using firewood for cooking, insects inside the dwellings and use of pesticides.

We detected multiple risk factors (i.e., social, environmental and health indicators) both in the municipal garbage dump (Fig. 1) and the brick producing site (Fig. 2).

Discussion

The underlying message of this investigation is that economic and social disadvantages carry an increased environmental exposures affecting children's health. The disparities that give rise to these circumstances are collectively known as environmental injustice.

Our data showed that children from the brick producing site (segregation index 5) and municipal garbage dump (segregation index 4), are exposed to high levels of multiple toxic agents (e.g., burning of solid waste and firewood, use of pesticides), and showed the highest morbidity rates and malnutrition, anemia, dental fluorosis, and the lowest IQ. Similar findings have been reported in South Africa and Jordan [26, 27]. This picture reflects excess social risk factors that further heighten children's vulnerability to environmental hazards. By contrast, children from the central zone (segregation index 2) showed a better health status (except for upper respiratory diseases); a likely explanation is concentrations of ozone, nitrogen dioxide and particulate matter in urban areas frequently exceeding safety thresholds, as reported by Romieu et al. [28]. The overall results of this investigation, however,

Table 5 Results of prevalence odds ratios (POR) for the direct health determinants group indicators (DHD) in Central Zone (CZ), Brick Producing Zone (BPZ) and Municipal Garbage Dump (MGD)

Direct health determinants (DHD)	Study sites (segregation index)	POR	CL 95	Chi^2 Mantel-Haezsel	*P* value
Respiratory infections	CZ (2)	1.00			
	MGD (4)	2.78	(1.51–5.14)	12.50	0.0004
	BPZ (5)	3.03	(0.93–5.52)	14.58	0.0001
Parasites	CZ (2)	1.00			
	BPZ (5)	1.41	(0.73–2.74)	1.20	0.2728
	MGD(4)	4.32	(2.27–8.27)	23.73	<0.0001
Lead	CZ (2)	1.00			
	MGD (4)	4.20	(2.22–7.96)	23.35	<0.0001
	BPZ(5)	6.61	(3.41–12.9)	38.72	<0.0001
Fluoride	CZ (2)	1.00			
	MGD (4)	2.63	(1.39–4.98)	10.38	0.0012
	BPZ (5)	4.85	(2.38–9.95)	23.53	<0.0001
PAH	CZ (2)	1.00			
	MGD (4)	1.25	(0.62–2.51)	0.44	0.5078
	BPZ (5)	3.70	(1.64–8.45)	12.36	0.0004
POP	CZ (2)	1.00			
	MGD (4)	1.56	(0.86–2.83)	2.43	0.1193
	BPZ (5)	1.91	(1.05–3.48)	5.12	0.0236
Intellectual quotient	CZ (2)	1.0			
	BPZ (5)	46.5	(13.01–197.8)	73.3	<0.0001
	MGD (4)	52.7	(14.71–224.7)	79.3	<0.0001

Table 6 Results of prevalence odds ratios (POR) for the social and environmental determinants group indicators (SD) in Central Zone (CZ), Brick Producing Zone (BPZ) and Municipal Garbage Dump (MGD)

Social and environmental determinants (SD)	Study sites (Segregation index)	POR	CL 95	Chi^2 Mantel-Haezsel	*P* value
Low education	CZ (2)	1.00			
	MGD (4)	7.05	(3.61–13.87)	40.70	<0.0001
	BPZ (5)	10.0	(5.00–20.31)	54.08	<0.0001
Low income	CZ (2)	1.00			
	BPZ (5)	1.23	(0.67–2.25)	0.51	0.4730
	MGD (4)	4.45	(2.16–9.28)	20.22	<0.0001
Overcrowded	CZ (2)	1.00			
	BPZ (5)	6.43	(3.31–12.58)	37.28	<0.0001
	MGD (4)	7.75	(3.95–15.35)	44.29	<0.0001
Sanitation	CZ (2)	1.00			
	BPZ (5)	6.25	(2.45–16.60)	19.91	<0.0001
	MGD (4)	20.8	(8.23–54.79)	64.97	<0.0001
Firewood use and burning of solid waste	CZ (2)	1.00			
	BPZ (5)	19.6	(16.3–68.14)	45.4	<0.0001
	MGD (4)	68.3	(21.3–243.4)	102.9	<0.0001
Insects inside the dwellings	CZ (2)	1.00			
	BPZ (5)	1.45	(0.79–2.66)	1.67	0.1964
	MGD (4)	2.70	(1.41–5.17)	10.6	0.0041
Pesticide use inside the dwellings	CZ (2)	1.00			
	BPZ (5)	1.69	(0.88–3.25)	2.8	0.0911
	MGD (4)	2.56	(1.27–5.20)	8.22	0.0041

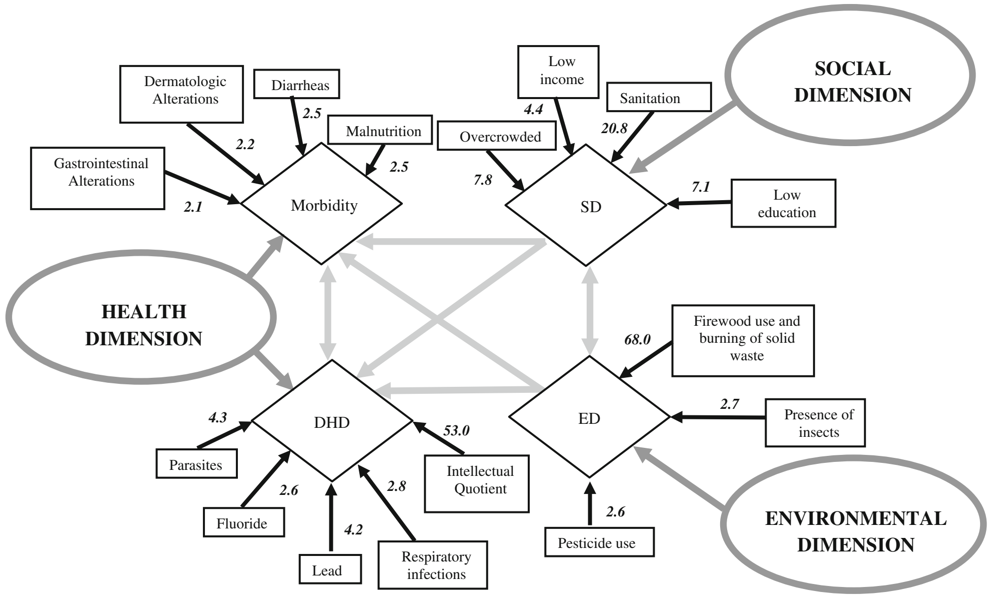

Fig. 1 Health risk scenario of municipal garbage dump (MGD) showing the risks (POR) of those indicators considered, by the population, as a major priority (*arrows*)

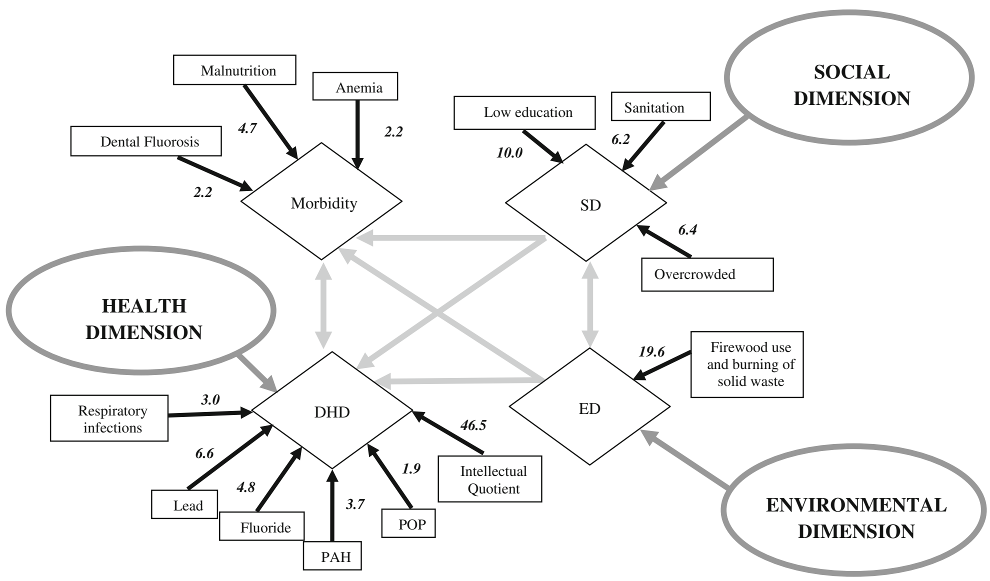

Fig. 2 Health risk scenario of the brick producing zone one population (BPZ), showing the risks (POR) of those indicators considered, by the population, as a major priority (*arrows*)

bear far-reaching policy implications and represent major challenges that have not received sufficient attention in Mexico. To our knowledge, this study provides original evidence concerning environmental injustice in our country.

The conceptual and methodological framework that we propose in this study allowed us to construct quantitative risk scenarios, in which specific weights are ranked according to risk values per indicator. The inclusion of central zone as reference group provided, on the one hand, a greater precision of the risk values and, more important perhaps, the necessary bases to design policies and a legal framework that specifically protect children against environmental exposures, on the other.

While identification of policies is a useful first step, the social will must also exist to implement them. In developed countries, progress towards protecting children from environmental risk factors has emerged out of a joint effort of academic researchers, government officials and advocates in translating knowledge from theory to population impact.

While a WHO Collaborating Center in Children's Environmental Health does exist at the University of San Luis Potosi, resources need to be established across other parts Mexico to ensure effective dissemination of knowledge about environmental risk factors across this large and geographically dispersed population. One model for the effective dissemination of knowledge about environmental risk factors is the establishment of regionalized Pediatric Environmental Health Specialty Units (PEHSU) where researchers, clinicians and advocates work together to identify, study and remediate local population concerns. This PEHSU should, however, not necessarily follow the North American's model. Novel approaches include strong emphasis on community outreach activities and links with advocates and lawyers. The principles of environmental justice may find a new area of work in Latin America's PEHSU model, and bring attention to basic children's rights.

We must point out limitations of this study, including the cross sectional design (that limits the possibility of establishing causal relationships), and lack of controlling for potential confounding factors (e.g., gender and age). Despite these limitations, our results strongly suggest that significant gaps remain in the system developed to protect children from environmental hazards in Mexico, a country that is likely to experience increases in scope of industrialization and potentially hazardous environmental exposures.

Conclusion

The development of this new methodical tool enhances the application of a series of indicators at the community level, building a unified vision of health and the environment, and opening the possibility of novel approaches to community health diagnoses and intervention programs. This kind of research will represent a novel public health perspective and environmental injustice issues in Mexico.

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