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ORIGINAL RESEARCH

Development of Environmental Health Indicators for the Child Population: Report on a Brazilian Experience

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Abstract

BACKGROUND This report presents the Brazilian experience on the elaboration of a matrix of children's environmental health indicators to the Brazilian Health Surveillance System. This experience was part of a project with the financial support of the Ministry of Health of Brazil to develop appropriate indicators for identification, measuring, and monitoring of the environmental risk factors to the children's health.

METHODS The methodology adopted for the development of the matrix of indicators of children's environmental health to Brazil comprised 3 steps. In the first step, the main causes of morbidity and mortality in the Brazilian population, aged 0-14 years, were identified, according to the data available from the Ministry of Health. The second step consisted of the identification of the Brazilian public-access information systems, with available official data regarding environmental, health, and socioeconomic conditions. In the third step, a preliminary matrix was elaborated. Correlation analyses were done to determine the indicators that would constitute the final matrix.

FINDINGS The selected indicators allowed the identification and surveillance of cancer, injuries, adverse birth outcomes, diarrheic and respiratory diseases, associated with environmental risk factors, in the Brazilian child population. The existing Brazilian official information systems provided data with the necessary quality for the construction of children's environmental health indicators. Nevertheless, some official systems on health information presented limitations related to the data availability over the course of time and timeliness of data capture. Concerning the environmental information, the major limitation was accessibility.

CONCLUSIONS A matrix of indicators of children's environmental health to Brazil can come to contribute to the implementation of a surveillance system of children's exposure to environmental contaminants in Brazil.

KEY WORDS children's health, environmental health, indicators, environmental pollutants, information systems

INTRODUCTION

According to the World Health Organization (WHO), environmental conditions are responsible for the deaths of approximately 3 million children aged $\leq$5 years worldwide per year. Respiratory infections and diarrheic diseases are the main causes of this high number of deaths and, respectively,

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correlated with environmental problems in 60% and 90% of the cases. Furthermore, the child survivors continue to be exposed to adverse environmental conditions, which may result in developmental problems that could lead to current and future diseases.[1,2]

The Pan-American Health Organization has estimated that approximately 100,000 children younger than age 5 years die each year as a result of environmental hazards in the region of Latin America and the Caribbean. Additionally, about 30% of the proportionate mortality of children younger than age 14 years, from respiratory and diarrheal diseases, could also be related to poor environmental conditions.[3,4]

Suk et al[5] report the preoccupation of members of the WHO Collaborating Centres for Children's Environmental Health about the threat of environmental pollutants to children's health. The authors emphasize the need for much more attention to environmental pollution as a risk factor for disease, mainly in low- and middle-income countries.

This situation of socioenvironmental vulnerability highlights the need for continual monitoring of these conditions. The elaboration of indicators constructed using reliable, up-to-date data could help managers to implement specific actions for each intervention required. These indicators should follow certain defined criteria, particularly regarding their scientific validity and reliability. An indicators system will be more reliable if it is more representative of the regional characteristics and the environmental and social determinants of each territory.

The harmful exposures considered more relevant to the children's development arise from the places where they spend most their time, such as as their homes, schools, and neighborhoods. In addition, the biological characteristics of this age group and the social conditions where they live have a fundamental role in the impact of environmental pollutants on children's health.[3]

The establishment of information systems is strategic for monitoring the progress of environmental, health, economic and social conditions.[6] Suitable information leads to the formulation of public policy or specific programs, that should be based on the available tools and possible actions in each territory.[1] The organization of an indicators system that identifies the relationship between the children's health and the exposure to environmental pollutants is fundamental to the achievement of these health surveillance actions.[7]

This article presents the experience that has been undertaken in Brazil of the development of a matrix of environmental health indicators for the child population. It has the objective to contribute to the organization and implementation of an interinstitutional network for the development of health surveillance actions related to children's exposure to environmental pollutants.

DEVELOPMENT OF ENVIRONMENTAL HEALTH INDICATORS FOR THE CHILD POPULATION

The International Scenario. Many debates have been occurring in the global scenario about the fundamentals that should be considered for the development of children's environmental health indicators. These indicators should be based on information that describes the children's health condition related to environmental determinants. In 2002 a global initiative on children's environmental health indicators was launched at the World Summit on Sustainable Development, with participation of government, nongovernment, and intergovernmental organizations, with support from the World Health Organization and the United States Environmental Protection Agency. In 2003, Briggs,[7] on behalf of the World Health Organization, published a list of indicators grouped according to specific morbidities, with a description of the models applied to their definition, and of the environmental factors relevant to the children's health.

In 2004 the Pan-American Health Organization (PAHO) proposed a preliminary list of children's environmental health indicators during a meeting carried out with countries of the region of Latin America and the Caribbean.[8] PAHO also published a catalog of indicators linked to the air and water quality and chemical exposure, in association with the Commission for Environmental Cooperation of North America, in 2006.[9]

In 2009 the World Health Organization organized a summary of the processes, outcomes, and key findings of the children's health indicator projects performed as part of the global initiative on Children's Environmental Health Indicators.[10] Countries and projects from Africa, Americas, European, and East Mediterranean regions contributed to this WHO initiative.

In 2011 a pilot study was performed in 6 countries of the region of the Americas examining the sources and criteria of capture and analysis of the

health and environmental data existing in Barbados, Panama, Mexico, Brazil, Nicaragua, and Paraguay.[6] The objective of this study was to standardize the monitoring of these data in these countries. Montoya et al[6] also presented a list of 39 indicators that could represent the existing relationship between the child health and the exposure to environmental pollutants in the region of Latin America and the Caribbean.

The Brazilian Experience. In 2011 the Ministry of Health of Brazil subsidized a project, undertaken by the Federal University of Rio de Janeiro, to develop appropriate indicators for identification, measuring and monitoring of the environmental risk factors to the children's health.[11]

Two guidance assumptions constituted the fundamentals for the elaboration of this matrix. First, the indicators should be easily handled by government decision makers on every level: municipalities, states, and national. The decision makers should participate not only in the identification and development of indicators but also should manage them for the monitoring of impacts of the environment on children's health. Consequently, the indicators should be defined from an open-access database and without the necessity of high-complexity statistical methods for their calculation.

Second, following the recommendations of Carneiro et al[12] to the development of environmental health indicators, they "should be built based on the priorities considered by the society as a problem, and should lead to health protection and the promotion of changes."

The methodology applied on the elaboration of this matrix of children's environmental health indicators to the Brazilian Health Surveillance System is discussed next.

ELABORATION OF A MATRIX OF CHILDREN'S ENVIRONMENTAL HEALTH INDICATORS TO BRAZIL—THE METHODOLOGY

The methodology adopted for the development of the matrix of indicators of children's environmental health to Brazil was based on the 2 guidance assumptions mentioned earlier: the easy handling by government decision makers and the society's priorities. It comprised 3 steps that followed a sequential logic. In the first step, the main causes of morbidity and mortality in the Brazilian population, aged 0-14 years, were identified, according to the data available from the Ministry of Health. The second step consisted of the identification of the Brazilian public-access information systems, with available official data regarding environmental, health, and socioeconomic conditions. These data were analyzed to assess their potential for use in the construction of the indicators of interest. In the third step, a preliminary matrix was elaborated and was evaluated by a panel of specialists and professionals. Correlation analyses were done to determine the indicators that would constitute the final matrix. These 3 steps are described with more details next.

Step 1: Exploratory Study of the Main Causes of Morbidity and Mortality Among Brazilian Children Aged 0-14 Years. The 5 main causes of death among Brazilian children aged 0-14 years were identified through an estimation of mortality rates from the database of the Health Information Department of the Brazilian health system.[13] These rates were evaluated in line with the following age subgroups: <1 year, >1-4 years, 5-10 years, and >10-14 years. The hospital admission rates from respiratory and diarrheic diseases, leukemia, and central nervous system (CNS) tumors were also calculated.

These morbidities were analyzed conforming to their relationship with environmental risk factors reported in the scientific literature. Among the cancers, the mortality rates and the hospital admission rates caused by leukemia and central nervous system (CNS) tumors were selected because of their possible association with pesticide exposure. Adverse birth outcomes data were included as a proxy for exposure to environmental contaminants. Several studies[14-17] have indicated an association between parental exposure to pesticides and occurrences of congenital defects and exposure to air particulate matter and occurrences of low birth weight.

Step 2: Identification and Evaluation of Existing Official Information Systems. The public-access information systems capable of supplying data that could apply to the elaboration of environmental health indicators were identified through searches on the government officials' websites. These searches lead to the selection of existing environmental, economic, demographic, and social data, considered in the scientific literature as environmental risk factors, associated with the morbidities listed in step 1. The data contained in these information systems were identified and analyzed in agreement with the following criteria: ease of access, coverage, availability over the course of time, timeliness of data capture, underreporting levels, trustworthiness, and degree of precision of the

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Table 1. Websites of Official Information Systems From Brazil Identified as Capable of Supplying Data That Could Be Used to Construct Child Environmental Health Indicators

Information System*	Website	Subsystems/Data Sources	Information	Observations
DATASUS/MS	http://datasus.saude.gov.br/	**SIM**: Mortality Information System. **SINASC**: Live Birth Information System. **SINAN**: Notified Disease Information System. **SIH-SUS**: Hospital Information system. **SIAB**: Primary care information system. **SIA-SUS**: outpatient information system	Morbidity and mortality relating to accidents and violence, cancer, adverse birth outcomes, and respiratory and diarrheic diseases.	**SIM**: high number of death certificates on which the underlying cause of death is described as "undefined." **SINAN**: (i) undernotification; (ii) the large amount of information that is not entered, particularly at times of major epidemics; (iii) the existence of information only on diseases for which notification is compulsory; and (iv) the existence of diseases for which notification should be provided as soon as there is a suspicion but remain unconfirmed for long periods. **SIH-SUS**: (i) the data relate only to cases of certain diseases that require hospital admission and do not take into account all cases of the disease; (ii) the existing data relate only to hospital admissions occurring within the public system and in hospitals that have service agreements with SUS, thus leaving out the cases that are handled through the private system; (iii) a single case of a given disease may be responsible for more than 1 hospital admission, and thus the data in this system cannot describe the exact number of cases.
SINIMA/MMA	http://www.mma.gov.br/		Climatic changes and heat concentration.	Information systems are not correlated with the health information systems.
IBGE	http://www.ibge.gov.br/home	**National census**: every 10 years. **Population-based sampling surveys**: PNAD; PNSB.	Basic sanitation, home condition, air pollutant concentration, pesticide trade.	**PNAD**: National Household Sampling Survey—basic surveys have been made available every year since 2001. Information is made available in aggregated form (tables) organized into major topics: "general data," "migration," "education," "work and income," "fertility," "families," and "homes." **PNSB**: National basic sanitation survey—information on water supply, sewage discharge, solid waste, and rainwater management was first conducted in 1974, and it has been conducted at irregular intervals.
DENATRAN	http://www.denatran.gov.br		Quantification of the vehicle fleet.	Data are available per type of vehicle, region of Brazil, state, municipality, and month.

DATASUS, Health Information Department of the Unified National Health System, Ministry of Health of Brazil; DENATRAN, National Traffic Department; IBGE, Brazilian Institute of Geography and Statistic; PNAD, National Household Sampling Survey; PNSB, National Basic Sanitation Survey; SIAB, Primary Care Information System; SIA-SUS, Outpatient Information System; SIH-SUS, Hospital Information System, SIM, Mortality Information System; SINAN, Notified Disease Information System; SINASC, Live Birth Information System; SINIMA/MMA, National Environmental Information System, Ministry of Environment.

measurements. Further information about the official information systems and their scopes and limits are presented in Table 1.

Step 3: Building of Matrix of Environmental Health Indicators for the Child Population. The patterns of morbidity and mortality consonant with the selected environmental, economic, demographic, and social data considered as environmental risk factors were organized into a preliminary matrix of environmental health indicators appropriated for the child population. It was elaborated on based on the following morbidities: adverse birth outcomes, respiratory diseases, diarrheic diseases, injuries (accidents/violence), and cancer (leukemia and CNS tumors).

This preliminary matrix of children's environmental health indicators was presented at a panel of specialists and government decision makers in a workshop organized by the Ministry of Health of Brazil. These professionals evaluated and discussed the applicability of this matrix as part of their surveillance activities.

A mixed ecological design study was employed to evaluate the correlation between the exposure variables and the identified morbidities among different groups and time periods. The correlation analysis considered the socioeconomic and environmental variables (exposure variables) as independents and the outcomes variables as dependents, with a 95% confidence level. Those variables capable of reflecting these associations were considered able to be used as environmental health indicators for the child population. They are presented in Table 2.

Subsequently, these indicators were characterized in consonance the Driving/Force, Pressure, State/Situation, Exposure, Effects, Action model and organized in a matrix of children's environmental health indicators for Brazil (Table 2).

FINAL CONSIDERATIONS

The methodology adopted in the elaboration of this matrix of children's environmental health indicators deserves some considerations. Although it has permitted the application of the 2 guidance principles, the easy handling by government decision makers and the society's priorities, it also determined some restriction on the proposition of indicators.

Because this methodology employed existing data in the information official systems, some other relevant indicators for children environmental health, like the identification of outcomes related to neurodevelopment, were not included because there did not exist available data about this issue in these systems. The same limitation was encountered related to epidemiological data on children's exposure to lead, mercury, persistent organic pollutants, and other pollutants that have a substantial impact on children's health.

A similar limitation is observed when the Brazilian matrix of children's environmental health indicators proposed in this manuscript is compared with the matrix of children's environmental health indicators presented by Montoya et al[6] for the countries in the region of the Americas. Some proposed indicators are common for both matrices like access to drink water, sanitation, the mortality rate from respiratory and diarrheic diseases, and incidence of birth defects. The same is observed for some exposure indicators like air pollution and the pesticide import rate. Nevertheless, because in the Brazilian official information systems there are not reliable data about malnutrition, overweight, and obesity, as well as on tobacco smoke and lead exposure, these indicators were not proposed. It is noteworthy that because the cancer mortality data from children and adolescents in the Brazilian health information systems are very trusty, some indicators are suggested in the Brazilian matrix but not in the Americas region matrix.

Beyond these considerations, the existing Brazilian official information systems provided data with the necessary quality for the construction of children's environmental health indicators. Nevertheless, some official systems on health information presented limitations related to the data availability over the course of time and timeliness of data capture. Concerning the environmental information, the major limitation was accessibility. The data about pesticide trade from a database of the Ministry of Agriculture of Brazil, Phytosanitary Pesticides System (AGROFIT), do not permit public access. Additionally, the air pollution data are obtained only in areas with existing weather stations and usually these stations are not located where health data are collected.

The selected indicators allowed the identification and surveillance of cancer, injuries, adverse birth outcomes, and diarrheic and respiratory diseases associated with environmental risk factors, in the Brazilian child population. In this way, this matrix can come to contribute to the implementation of a surveillance system of children's exposure to environmental contaminants in Brazil, which is

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Table 2. Socioeconomic and Environmental Variables (Exposure Variables), Outcome Variables, and Indicators According to Morbidity

Morbidity	Exposure variables	Outcome variables	Indicators	FPSEEA
Adverse births effects	Housing density Income No. of vehicles No. of maternal school years Pesticide trade	Annual fetal and early (<7 d) neonatal mortality rate Live births with low weight Live births with congenital malformations* Live births with CNS congenital malformations*	Housing density Woman of fertile age living in area with atmospheric pollution Vehicle density Agricultural pesticide consumption Mother's schooling level Perinatal mortality rate Low weight at birth rate CNS congenital malformations at birth	Situation Exposure Exposure Exposure Exposure Effect Effect Effect
Respiratory diseases	• Population density • Lack of gas stove at home • No. of vehicles	• Annual mortality rate† from respiratory diseases • Annual mortality rate† from asthma • Hospital admission rates from lower and upper respiratory diseases	Housing density Children living close to intensive vehicle traffic Children living in areas with pollution as a result of particulates Morbidity as a result of respiratory diseases of the upper airways, respiratory allergies, allergic rhinitis, otitis media, bronchitis, asthma, pneumonia Mortality as a result of infection of the lower airways.	Situation Exposure Exposure Effect Effect
Diarrheic diseases	• People living without basic sanitation • People living without drinking water • People living in settlements	• Annual mortality rate† from diarrheic diseases • Hospital admission rates from diarrheic diseases.	Failures of the water supply system People living in informal settlements Children living in housing without basic sanitation Mortality rate as a result of diarrhea Morbidity rate as a result of diarrhea	Situation Exposure Exposure Effect Effect
Injuries (accidents /violence)	• People living in settlements • Child labor • No. of vehicles • income • No. of maternal school years	• Mortality rate from work accidents‡ • Mortality rate from traffic accidents‡ • Incidence rate of traffic accidents‡ • Incidence rate of negligence / abandonment‡ • Mortality rate from homicides‡	Children involved in regular work People living in informal settlements Children living in areas affected by disasters Children living close to roads with intense traffic Mortality rate as a result of violence Morbidity rate as a resul violence; transport accidents; intoxication; exposure to the forces of nature.	Situation Exposure Exposure Exposure Effect Effect
Cancers	• No. of vehicles • Pesticide trade	• Annual mortality rate* from leukemia • Annual mortality rate* from CNS tumors • Hospital admission rates from leukemia and from CNS tumors	Agricultural pesticide consumption Children living in areas with pollution Vehicle density Mortality rate as a result of leukemia and CNS tumors Morbidity rate as a result of leukemia and CNS tumors	Exposure Exposure Exposure Effect Effect

CNS, central nervous system.
* According International Statistical Classification of Diseases and Related Conditions, 10th revision, in all live births (×100) per year.
† For children <14 years old per 1,000 population 0-14 years old.
‡ For children <14 years old per 100,000 pop between 0-14 years old.

essential to prevent harmful effects on health population, mainly the most vulnerable groups, such as children.

The improvement of environmental information systems embracing the identification and registration of children's exposure to environmental pollutants, like metals, persistent organic pollutants, and others, is fundamental to the establishment of a wide-ranging and reliable children's environmental health indicators surveillance system.

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