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ORIGINAL ARTICLE

Association between exposure to urban waste and emotional and behavioral difficulties in schoolchildren☆

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Abstract
Objective: To evaluate the association between living near waste recycling sites and emotional or behavioral difficulties in schoolchildren.
Methodology: A cross-sectional study with schoolchildren aged 6–13 years old from disadvantaged communities in a Brazilian city, divided between those who live less than 100 m away from the central point of the recycling site and those that live more than 150 m away from the site, as a control group and classified through georeferencing. The emotional and behavioral difficulties were investigated using the Strengths and Difficulties Questionnaire tool. Other variables were analyzed through logistic regression to determine their contribution to the outcomes.
Results: Children living near waste recycling sites had a higher prevalence of emotional and behavioral problems than children living farther away. In the logistic regression model, no other covariates had a significant impact on the results, except for attending preschool. As expected, the families of the exposed group had lower income and lower levels of schooling, thus being characterized as a highly vulnerable population.
Conclusion: The association between living near waste recycling sites and lower test performance raises concerns about the impact of inappropriate waste management in urban centers on children's health.

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PALAVRAS-CHAVE
Resíduos;
Transtornos do neurodesenvolvimento;
Testes neuropsicológicos

Associação entre exposição a resíduos urbanos e dificuldades emocionais e comportamentais de escolares

Resumo
Objetivo: Avaliar a associação entre habitar próximo a sítios de reciclagem e dificuldades emocionais ou comportamentais em escolares.
Metodologia: Estudo transversal com escolares de 6 a 13 anos de comunidades desfavorecidas em uma cidade do Brasil, divididas entre aquelas que tem sua residência situada a menos de 100 metros de distância do ponto central do sítio de reciclagem e aquelas que habitam a mais de 150 metros, como grupo controle e classificadas através de georeferenciamento. As dificuldades emocionais e comportamentais foram investigadas através do instrumento *Questionário de Capacidades e Dificuldades*. Outras variáveis foram analisadas através de regressão logística para determinar sua contribuição para os desfechos.
Resultados: Crianças que vivem próximas a locais de reciclagem de resíduos tiveram maior prevalência de problemas emocionais e comportamentais do que as crianças que vivem mais afastadas. No modelo de regressão logística, nenhuma outra covariável apresentou impacto significativo sobre os resultados, à exceção de haver frequentado pré-escola. Como esperado, as famílias do grupo exposto apresentaram menor renda e menores níveis de escolaridade, caracterizando-se como uma população altamente vulnerável.
Conclusão: A associação entre a habitação próxima a locais de reciclagem e um menor desempenho nos testes levanta preocupações sobre o impacto do manejo inadequado de resíduos nos centros urbanos sobre a saúde das crianças.

Introduction

It is estimated that almost one-fifth of school-age children suffer from some emotional or behavioral disorder.[1–3] These disorders are often associated with mental illness, which in half of the cases occurs at or before the age of 14 years.[1] The central nervous system (CNS) can be greatly affected by environmental exposures during childhood, a period of high vulnerability to neurodevelopment,[4] and the outcomes caused by toxic substances may require a long time after exposure to be noticed. Children have explorative behaviour and poor perception of possible risks. Additionally, the metabolic detoxification routes of many pollutants are immature and function poorly in childhood, making the impact of chemical and biological waste exposure much greater in this age group.[5] These characteristics cause many environmental exposures to be neglected as a cause or predisposing factor of disease.[5,6]

Much has been investigated about the exposure to substances in urban waste, such as lead, cadmium, organophosphorus pesticides and other compounds, and their effects on neurodevelopment.[7–9] Unfortunately, in developing countries, the inappropriate disposal of these pollutants in urban waste is still frequent. Very often, people resort to recycling urban waste as a last resort for obtaining income to survive.[10] In these scenarios, it is common for the waste to be recycled in their own houses or in areas adjacent to the recyclers' houses, leaving the entire community exposed to the chronic effects of inhalation, dermal contact, and ingestion of pollutants.[11] Although much is known about many of these pollutants, the effects caused by the continuous proximity of these substances over the years, during a critical neurodevelopmental period, are not yet clear. The sporadic measurement of metabolites has limitations, because exposure to a pollutant may be intermittent, which may lead to false negatives in the exposure characterization. Furthermore, the generalization of the effects of a specific pollutant on the CNS is limited, since the composition of discarded waste can be extremely variable at each site, depending on habits, seasonality, economic activity, and the public service network available in the communities.[10] Considering these limitations, it is necessary to study the exposure not to a specific pollutant, but to the overall exposure as it occurs, directly focusing on the proximity of children to the site of waste storage and separation.

This study evaluated the association of living near urban waste recycling sites with scores of emotional and behavioral difficulties in schoolchildren from a Brazilian city, in low-income communities, where much of the waste is locally separated and processed.

Methods

A cross-sectional case–control study was carried out with children from communities with urban waste recycling sites in the city of Caxias do Sul/RS. In this city, much of the waste is handled by cooperatives or family organizations that carry out the waste separation and disposal in their own households or next to their households. This waste comes from residences, industries, and companies located in the city. The children were selected among schoolchildren aged 6–13 years old, who lived in two neighbourhoods where recycling takes place in the open air and without protective barriers against circulation in children. The criterion for the children's allocation was living up to 100 m away from an open recycling site; the control group was selected among schoolchildren who lived in the same community, but more than 150 m away from the recycling centre, allowing a washout zone between the exposed children and the control group. The cut-off criterion for distances was based on studies evaluating air pollution, since there are no well-defined cut-off points, to the best of the authors' knowledge, determining the impact of the proximity of mixed waste recycling sites (organic, chemical, and inorganic, indiscriminately) on neurodevelopment.[12,13]

The determination of the central point and the research participants' homes was made through georeferencing. This technique is widely used in environmental research to determine the effect of spatial location and distances in relation to a pollutant. Traditionally used to investigate infectious diseases and epidemics, the method also applies to other environmental hazards, such as in research with urban waste, recycling sites, radioactive, and electromagnetic sources.[14] The Map Plus application (Miocool Inc., version 2.6.9, Duwei Technology Ltd.) was used to determine the housing and recycling points, and the Quantum Gis program (QGIS, version 2.14.20, QGIS Development Team) for the calculation of distances.[15]

The students were classified as having emotional and behavioral difficulties through the Strengths and Difficulties Questionnaire (SDQ) tool.[16] The SDQ is a free tool that has been translated and validated in more than 40 countries, including Brazil, aimed at assessing the mental health of children and adolescents.[17] The SDQ consists of 25 items, divided into five subscales: problems in prosocial behaviour, hyperactivity, emotional problems, behavioral, and relationship problems. Each of the 25 items receives a score between zero and 2 and the questions of each dimension are mixed with those of another dimension, preventing response bias due to inertia or reinforcement/negation bias. Each dimension was tabulated, and each participant was classified according to the protocol as ''normal'' or ''abnormal.'' In this study, since SDQ is a tool for research and screening for emotional and behavioral difficulties of schoolchildren (and not for nosological diagnosis), the protocol recommendation was followed, assigning the result ''abnormal'' to the children with borderline scores.[17] The combination of the sub-area scores generates a final test result, which is divided into ''normal'' and ''abnormal'', and this overall score is the main outcome.

Blinding was not possible because the home was precisely the factor being studied. The evaluators sensed the waste odours in many cases, especially in those closest to the recycling centre. Because this was a highly vulnerable population, the option of transporting the parents/guardians to another place to answer the questionnaire was not considered, avoiding the loss of participants. The choice of collecting the data in the households was also aimed at preserving the well-being of the study participants and their parents/tutors, minimizing changes in the families' routines.

Initially, the sites were visited by a group of researchers from the Nucleus of Studies and Research in Public and Social Policies of Universidade de Caxias do Sul, who already carry out community support work. Both neighbourhoods have a Basic Health Unit with Family Health Strategy teams. From the recycling points, identified by the team and marked in the software, the team started out eccentrically in the streets adjacent to the recycling site, from house to house, in search of children of the study age group. Children without a parent/guardian available to answer the SDQ tool were excluded from the study. Subsequently, the questionnaires were applied regarding the child's perinatal, demographic, and neurodevelopmental data. The SDQ was applied to parents or guardians. Regarding the control group children, the georeferencing software showed that there were no other recycling sites within a distance less than 150 m for each marked home; the distance to the nearest recycling centre also was measured (Fig. S1).

A sample size of 76 children in each group was calculated, with an estimated prevalence of 10% of children with difficulties in the non-exposed group and 30% in children from the exposed group, with a significance level of 5%, a power of 90%, and a margin of 15%. To evaluate the association between waste exposure and emotional and behavioral difficulties, the authors used Pearson's chi-squared test for categorical variables, Student's *t*-test for the comparison of the means of the groups regarding the continuous variables with normal distribution, and the Mann–Whitney test for non-parametric variables. Logistic regression was performed to evaluate the effect of each variable on emotional and behavioral difficulties, including covariables with a potential impact on children's neurodevelopment, such as low birth weight, high number of siblings (≤ 4), and low maternal schooling (incomplete elementary school). Data analysis was performed using the software IBM SPSS (IBM SPSS Statistics for Windows, version 22.0, NY, USA).

Study participation was voluntary, and the parents or guardians were informed and signed the informed consent, according to resolution 466/2012 of the National Commission of Ethics in Research (*Comissão Nacional de Ética em Pesquisa* CONEP). The study was authorized by the Institutional Research Ethics Committee, through Opinion No. 2.172.721.

Results

A total of 153 children were included, with a slight predominance (54%) of males. Although there was a significant difference in family income between the groups, the sample was generally characterized by a low-income population and low maternal schooling. However, there was no difference between groups regarding indicators of poor perinatal care that could represent a greater risk to the nervous system.

There was a decrease in the SDQ score of children living near recycling sites when compared to those living more than 150 m away. This reduction persisted even after controlling for confounding factors among some covariables in the logistic regression model.

Due to the characteristics of the exposure and housing near recycling sites, there was a difference between the groups regarding family income, which was higher in the control group ($p < 0.01$). This variable was later included in the logistic regression model. Similarly, the maternal schooling level, used as another marker of socioeconomic status, was also different between the groups, with a higher

Table 1 Children's characteristics in the exposed groups (housing less than 100 m from the recycling site) and control group (more than 150 m away).

Variable	Exposed	Non-exposed	p
Age (months)[a]	121 (27)	122 (26)	0.7
Birth weight (g)[a]	3234 (437)	3091 (439)	0.05
Apgar score in the 5th minute[b]	9 (8–10)	9 (8–10)	0.9
Weeks of gestation[a]	39.4 (1.8)	38.7 (1.5)	0.6
Postnatal hospitalization days[b]	2 (1–4)	2 (1–3)	0.6
Maternal smoking during pregnancy[c]	25 (33.7)	20 (26)	0.3
Low maternal schooling (up to incomplete elementary school)[c]	16 (20.7%)	40 (53%)	≤0.01
Family income (in R$/month)[b]	1300 (950–2000)	2570 (1500–3500)	≤0.01

[a] Mean (±SD).
[b] Median (IQ 25–75).
[c] %.

percentage of mothers with low schooling among the children in the exposed group. The studied population had low maternal schooling, including 92 mothers (60.1%) who only finished elementary school.

As for the other variables with potential to influence neurodevelopment, no significant difference was observed between the groups, except for the number of siblings, which was higher in the group of children exposed to recycling (Table 1).

Regarding the socioeconomic aspects of the sample, many variables showed relevant data regarding the characterization of the study population, even though there were no significant differences between the groups. Only one child in the entire sample did not attend school; however, a considerable percentage, 37% of the sample, did not have access to preschool, a period known to be fundamental to neurodevelopment. Other aspects that are usually relevant to neurodevelopment were also unfavourable: only 46.5% ($n = 67$) of the children were exclusively breastfed up to the 4th month of life; 29.8% of the babies ($n = 45$) had mothers who smoked during pregnancy, and 38% did not live with both parents at home (Table 2).

Six recycling sites were identified through an active search that had no access barriers for children in the two assessed neighbourhoods. The perimeters of inclusion and of the controls were established from the central point of these sites. The mean distance from the home to the recycling site was 52 m (±26) in the exposed group and 346 m (±183) in the control group ($p < 0.01$). The period of time living in the house, representing the child's contact with the recycling site, was not statistically different between the two groups ($p = 0.07$).

Regarding the findings on behavioral and emotional health subareas, assessed by the SDQ, none showed significant difference between the groups. However, when the test was evaluated as a whole, the number of children with low scores was higher in the exposed group (Table 3).

As for the risk factors regarding neurodevelopment, only distance less than 100 m from the recycling site was statistically significant in the logistic regression model. It was decided to include in the model low birth weight (<2500 g), high number of siblings (>4), low maternal schooling (incomplete elementary school or less) and having attended or not attended preschool, with the latter also being significant. Home location within 50 m from the recycling site centers was also evaluated, aiming to assess the intensity of exposure, but these data were not statistically significant (Table 4).

Some non-quantitative data were observed during data collection. Although not considered for analysis, these data reinforce the characterization of children's environmental exposure. One of these is the fact that there is little (if any) previous separation of waste deposited in the communities. The presence of chemical residues,

Table 2 Characteristics of postnatal neurodevelopmental risk between exposed and non-exposed children.

Variable	Exposed	Non-exposed	p
Child attended preschool[a]	50 (65)	47 (61)	0.5
Exclusive breastfeeding up to the 4th month[a]	29 (39)	38 (53)	0.09
Lives with both parents[a]	45 (59)	50 (65)	0.4
Time living in the household (in months, SD)	134 (82)	111 (78)	0.07
Number of co-inhabitants (mean, SD)	5.4 (1.8)	4.1 (1.3)	≤0.01
Number of siblings[b]	3 (1–5)	1 (1–3)	≤0.01

[a] n (%).
[b] Median (IQ_{25-75}).

Table 3 Total results of SDQ and assessed behaviour, and emotional health sub-areas.

Dimension of the SDQ test (*n*, %)	Exposed	Non-exposed	χ^2	*p*
Relationship problems	54 (71)	44 (57)	3.2	0.07
Hyperactivity	34 (44.7)	34 (44.2)	0.005	0.9
Behavioral problems	28 (36.8)	23 (30)	0.83	0.3
Emotional problems	28 (36.8)	20 (26)	2.09	0.1
Prosocial behavioral problems	5 (6.6)	3 (4)	0.55	0.4
Total SDQ altered	18 (23.7)	8 (10.4)	4.8	0.03

Table 4 Simple and adjusted analysis for covariables that are potentially harmful to neurodevelopment.

Covariables	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	*p* (Wald)	*p* (LR)
Less than 100 m	0.2 (0.11–0.39)	0.17 (0.06–0.5)	<0.01	<0.01
Less than 50 m	0.27 (0.11–0.67)	1.78 (0.47–6.68)	0.4	0.4
Low maternal schooling	0.31 (0.16–0.62)	0.89 (0.36–2.17)	0.8	0.8
More than four siblings	0.31 (0.11–0.85)	1.1 (0.33–3.66)	0.8	0.8
Low birth weight	0.1 (0.01–0.78)	0.16 (0.02–1.32)	0.09	0.06
Attending preschool	0.24 (0.12–0.49)	0.42 (0.18–0.97)	0.04	0.03

indiscriminately mixed with organic residues, including hospital waste, was observed. Several family recycling centers were also located, operating independently and with their own routines and standards for handling and separation of waste. Many of these accumulations of waste occupy the street and are easily accessible to children and bystanders (Fig. S2). The odour of decomposing organic matter was constant in all visits to the exposed group.

Discussion

An association has been demonstrated between living near waste recycling sites and worse performance at tests evaluating emotional and behavioral symptoms, even after controlling for other variables with potential for neurodevelopmental delay. To date, the authors are unaware of other studies specifically evaluating this association, except for one study that showed the proximity to a waste landfill as a neurodevelopmental impairment factor.[18] Several other studies have evaluated disposal sites of so-called ''electronic waste'', or ''E-waste'',[19] showing the association between living near sites dedicated to this type of activity and elevated serum levels of lead,[20] as well as other metals in hair[21] and soil samples, and even in foods.[22] However, these studies differ from the present one, because the composition of the residues found in the present study was a mix of organic matter, chemical substances, and metals, without previous separation.

Developing countries have a ''double environmental burden'',[23] as they deal with environmental issues related to industrialization at the same time that socioenvironmental risks related to poverty have not yet been fully resolved. In these situations, the impact on children's health is always higher than in adults.[24] The present study reflects this reality by investigating a highly disadvantaged population, with severe vulnerabilities, who live close to the waste of an industrialized, urban society. According to the World Health Organization, studies evaluating environmental exposures in children from countries such as those in Latin America are necessary not only for diagnosis, but also to assist in the adoption of public policies.[25]

An important aspect was the approach used concerning the exposure characterization. Several studies have been reducing the importance of measuring biomarkers, as exposures vary over time.[4,25] The eventually frustrated search for a single specific pollutant or biomarker in the assessed scenario could lead to the false conclusion of the absence of pollutants and, therefore, low environmental burden on the children.[26] In this study, the authors chose to adopt the ''exposome'' theory, which postulates that numerous environmental aggressions can participate synergistically in a particular outcome. According to the theory, it is more logical to assess exposure to waste as a whole, rather than searching for one of thousands of specific pollutants that may or may not be found. By focusing on the distance between the child's home and the recycling site, the authors draw attention to the child's routine instead of focusing on a specific marker.

As for the distance used to characterize the groups, it is known that some pollutants, especially small particulates and volatiles, can disperse for distances of up to kilometers,[4] but clearly the children closest to the waste and who circulate there have more direct exposure to chemical residues. However, since the authors did not find any previous studies determining exactly the distance of greatest impact in the case of mixed urban waste, it was decided to adopt the distance cut-off used in studies that evaluate air pollution, from 100 to 150 m.[12,27] As a secondary result, these data can support future studies using these distance cut-off points.

Especially in developing countries, little is known about the impact of environmental exposure on the health of children.[23] However, several assumptions of the present study are already well demonstrated: the exposure of large numbers of people to informal waste processing[28]; the vulnerability of children to environmental aggression[6]; and the effect of pollutants on the development of the central nervous system.[1,7,29,30]

The total of 17% of children with emotional or behavioral difficulties found in our study agrees with the literature.[2,3] One of the limitations of the present study was that the questionnaires were not applied to the children's teachers. In this case, it is possible that the numbers were higher, and perhaps they would show even greater vulnerability and impact due to the contact with the waste recycling. Although the tool (SDQ) is validated and widely used in many countries, including Brazil, it is possible that it was not completely understood by respondents, because of the cognitive limitations of this extremely disadvantaged population. However, there is no other tool that evaluates the same outcomes and that has been specifically developed to investigate this population.

Other factors associated with poor socioeconomic status could be postulated as confounding factors. These data were partially controlled through the adopted statistical analysis, but more confounding factors can be analyzed in future studies. It should also be noted that there was no statistically significant difference in the study's sub-areas of the test. This is possibly due to the sample size, calculated for the complete test, and not for its subareas. Similarly, the number of participants was calculated for the distance limitation of 100 m in the exposed group, which may explain why there was no significant difference regarding the results of the few children who lived even closer (less than 50 m) to the recycling sites. Nevertheless, the study addresses a neglected problem in urban centers, which is health security and the risks to children's health. To date, the authors are unaware of similar studies in Brazil, which combine georeferencing and the use of a validated tool such as the SDQ. It seems important to consistently address the problem from the perspective of health care teams and by environmental and health care managers.

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Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jped.2018.11.014.

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