# Impact of a waste disposal site on children physical growth

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## SUMMARY

*Background:* Several epidemiological studies have shown an increased risk of health problems among population living close to landfills. We evaluated the impact of a municipal solid waste disposal site on children's growth between 0-3 years of age.

*Methods:* Children were selected in sites likely to receive dispersion of air compounds from the waste disposal site and also in a control area, in Cali, Colombia, in 2005. Anthropometric measures were obtained at enrollment and in two follow-up visits at 3 months intervals to obtain standardized z scores of weight for height (WHZ) and height for age (HAZ). In addition, questionnaires including information of socio-economical conditions and morbidity were applied at enrolment and during follow-up visits.

*Results:* Children exposed had on average 0.16 less standard deviations (SD) in WHZ scores when compared to control group (95% Confidence Interval [CI]: -0.34, 0.01). Among those who have lived >50% of their life in the study area, a significantly lower HAZ score was observed (-0.12) associated with exposure. Our data also suggest a larger effect of exposure to the waste disposal site in WHZ among children with symptoms of respiratory disease than among asymptomatic children (p=0.08).

*Conclusions:* Exposure to this waste disposal site was found associated with lower children's growth indexes.

*Keywords:* Solid waste; Landfill site; Growth; Environment and public health.

*Impacto de un depósito de residuos sólidos en el crecimiento físico infantil*

## RESUMEN

*Antecedentes:* Varios estudios epidemiológicos han mostrado un aumento en el riesgo de presentar problemas de salud entre las personas que habitan cerca a los rellenos sanitarios. En este estudio se evaluó el impacto de un depósito municipal de residuos sólidos en el crecimiento de los niños entre 0 y 3 años de edad.

*Materiales y métodos:* Los niños expuestos se seleccionaron en sitios con alta probabilidad de exposición a los agentes provenientes del depósito por dispersión aérea. Se seleccionó un grupo control cuya distancia y ubicación hacía poco probable que estuviera expuesto a dichos agentes. Se obtuvieron medidas antropométricas a la captación y en dos visitas de seguimiento, con intervalos de 3 meses. Se obtuvieron los puntajes estandarizados de Z del peso para la talla (PT) y talla para la edad (TE). Además, se realizaron cuestionarios acerca de condiciones socio-económicas y morbilidad en la captación y en las visitas de seguimiento.

*Resultados:* Los niños expuestos tuvieron en promedio 0.16 desviaciones estándar (DE) menos en el PT al compararlo con el grupo control (intervalo de confianza 95% [IC]: -0.34, 0.01). Entre los que habían habitado >50% de sus vidas en el área de estudio, se observó un menor valor de TE (-0.12) asociado con la exposición. Los datos también sugirieron un mayor efecto de la exposición en el PT entre los niños que presentaron síntomas respiratorios durante el seguimiento en comparación con los niños que permanecieron asintomáticos (p=0.08).

*Conclusiones:* La exposición al depósito de residuos sólidos se asoció con un menor valor en los índices de crecimiento pondo-estatural.

*Palabras clave:* Residuos sólidos; Rellenos sanitarios; Crecimiento; Medio ambiente y salud pública.

Industrial development, population growth and uncontrolled migration to urban areas have notoriously increased production of solid waste. An evaluation carried out by the Pan American Health Organization (PAHO)[1] estimated that by 2001 Latin America daily produced around 369,000 tons of municipal solid waste, of which only 60-80% were collected and less than 25% had acceptable disposal.

To prevent environmental pollution in cities, landfill sites or controlled waste disposal sites are the most frequently utilized strategies. However, several epidemiological studies have shown an increased risk of health problems among population living close to these sites [2-6]. Research results are not conclusive, and World Health Organization (WHO) recommends that investigations should be done among vulnerable population such as newborns, children, pregnant women and seniors[7].

Growth in children is a complex process that can be influenced by many factors including environmental ones [8-11]. Some studies have explored the association between contamination and growth using crude measurements of height and weight, and in previous investigations a reduction of height associated to higher blood levels of contaminants and poorer air quality was reported[12,13]. However, the specific association between exposure to landfill sites and children growth has not been subject of research. One study carried out in 1987 among children living near solid waste polluted waters found that those who had lived around the site more than 75% of their life presented a significant reduction in percentiles of height-for-age, even after adjusting for socioeconomic conditions, parental height and chronic illness of children[6].

We present here a study that was part of a larger prospective cohort design carried out in Cali, Colombia, which included environmental evaluations and assessment of health effects of the municipal waste disposal site, the Navarro waste disposal site (NWDS), in three age groups: 0-3, 1-5 and >50 years of age. We show here results of the 0-3 years of age group follow-up to evaluate potential impact of this solid waste disposal site in the growth of children living in its area of influence.

## MATERIALS AND METHODS

*Study area.* The study was conducted in the urban area of Cali, located at an altitude of 960 meters above sea level and with an average temperature of 24º C. The zone selected as exposed to NWDS emissions was located in a perimeter of 0-3 km around the NWDS and in the predominant wind direction; while the control zone was selected at a distance >3 km and in the opposite direction to the predominant wind direction. An effort was also made to choose the zones so that they would be as similar as possible in as much as other environmental, topographic, and socioeconomic factors (urban/rural distribution, 2, 3 and 4 socioeconomic strata) or in other words, that the major difference between them would be their location in relation to the NWDS.

The neighbourhoods which fit with selective criteria as being exposed were the corregimiento of Navarro, located in a rural zone, and the neighbourhoods: Morichal de Comfandi, Ciudad Córdoba, and Caney, located in an urban zone. Neighbourhoods selected as control zone were the corregimiento de Hormiguero, located in a rural zone, and the neighbourhoods Departamental, Cristóbal Colón, León XIII and Conquistadores, located in an urban zone.

The parameter of interest for sample size calculation was the standardized Z score (growth indicator) using formulae for differences between means. A Z score of 0.00 DE was assumed for the control group and required sample size for different values of Z were calculated for the exposed group. In all calculations we used a significance level of 0.05, a statistical power of 80% and a correlation coefficient between measurements of 0.8. Hence, the estimated sample size was 300 children <3 years of age. The parents or tutors of the selected children were invited to participate and their informed consent was obtained, after explaining study's objectives and procedures. The protocol was reviewed and approved by the Institutional Review Board of the Universidad del Valle.

*Endpoints and covariates.* Anthropometric measurements were obtained at recruitment and in two follow-up visits with an interval of three months. The measurements were conducted by trained auxiliary nurses following the recommendations of the United States National Centre Guide for Health Statistics. The height in centimetres in supine position was taken for children <2 years of age and the standing height for children >2 years of age. The weight in kilograms was measured using a hanging balance. All the measurements were taken twice during each visit and were averaged

to reduce the measurement error.

The EPI-NUT program (Epi-Info 2000) was used to obtain the z-standardized of WH and HA. After detection of extreme data, the questionnaires were reviewed in order to discard possible errors in data entry. The extreme values which were not compatible with the expected physiological growth were codified as missing data. A total of 1,701 values of z were obtained and of these only 26 (1.5%) were codified as missing data.

Data collectors filled questionnaires which included information on socio-economic conditions and morbidity at recruitment and at follow-up visits. Information was also collected regarding educational level and occupation of parents, monthly income, social security affiliation, and access to public services, number of household inhabitants and house construction materials, as an indicator of socio-economic condition. The mother's weight as well as lactation information was also collected during the first visit. In addition, during each visit we collected information on acute disease (i.e. respiratory symptoms or diarrhoea) and documented changes on the monthly income.

*Data management and analysis.* Questionnaires were applied by trained health workers and reviewed by a field supervisor to correct inconsistencies. Normal distribution of Z scores was checked to allow use of Gaussian based statistical methods. Scores were initially summarized and compared between exposed and control groups at each visit. Linear regression analysis was carried out using generalized estimating equations (GEE) to account for the correlation between repeated measures over time[14]. Estimates of NWDS exposure effect in children growth were adjusted by mother height, socioeconomical variables and acute morbidity incidence. Effects were also stratified by children age (i.e.; <24 and >24 months) to evaluate heterogeneity in growth indicators between these two groups. To assess effect modification by acute morbidity during follow-up and proportion of lifetime living in the area, multivariate models were stratified accordingly.

## RESULTS

Between July 2005 and January 2006, a total of 1,972 homes were visited in the study area and 354 children <3 years of age were included in the exposed group, while 325 were enrolled in the control group. Median duration of follow-up was 6.3 months (interquartile range [IQR]: 4.9-6.8) and median interval between visits was 3.3 months (IQR: 2.0-4.7). Among children enrolled, 181 (26.6%) were lost to follow-up (128 at the second visit and 53 at the third). Individuals were similarly lost in exposed and control groups (13.8% *vs.* 13.3%, respectively), and no differences were found, in terms of demographic and clinical characteristics, between those initially enrolled and individuals lost to follow up (data not shown).

Even though an attempt was made to maintain a similarity between the exposed and control zones, it was observed that the exposed group enjoyed in general, better socio-economic conditions. Specifically, the children in the exposed group had parents with a higher educational level (technical or university training 25.2% *vs.* 17.8%), had a larger proportion of affiliates to the social security regime (61.8% *vs.* 36.7%), had a higher family income (>1 minimum monthly salary 62.3% *vs.* 43.8%) and had a larger access to public services (with access 85.8% *vs.* 66.4%) than the children in the control group. There were no differences in regards to maternal lactation, vaccination state, or maternal height. Additionally, the children in the exposed group presented a higher frequency of episodes of acute diarrhoea at the time of the first visit (44% *vs.* 18.6%) and during the follow-ups had a higher frequency of respiratory symptoms (50.6% *vs.* 37.6%).

Crude means of WHZ were consistently lower at each visit in the exposed group as compared to the control group (0.05 *vs.* 0.12; -0.12 *vs.* 0.16; y 0.06 *vs.* 0.13). This difference reach statistical significance in the second visit (p<0.001) when mean WHZ was -0.12 in the exposed group (95% confidence interval (CI): -0.26; 0.01) and 0.16 among control children (95% CI: 0.04; 0.29). Crude means of HAZ were also lower among exposed children during the second and third visits (-0.27 *vs.* -0.19; y -0.17 *vs.* -0.13), but these differences were not statistically significant.

Table 1 summarizes longitudinal multiple regression estimates for determinants of WHZ score during follow-up. After adjusting for demographic, socioeconomic and morbidity variables, children exposed to NWDS had on average 0.16 less standard deviations in WHZ scores when compared to control group (p=0.06). No significant differences were observed in the adjusted effect of landfill exposure in HAZ (difference= -0.06; 95% CI:-

**Table 1**
**Determinants of WHZ score according to exposure to Navarro Waste Disposal Site and**
**socio-demographic and clinical cofactors in a cohort of 0-3 years old children in Cali, Colombia, 2006**

| Variable | Coefficient (95% CI) | P value |
|---|---|---|
| Exposure to NWDS | -0.16 (-0.34, 0.01) | 0.06 |
| Age (months) | | |
| <12 | reference | - |
| 12-24 | -0.20 (-0.37, -0.03) | 0.02 |
| >24 | -0.43 (-0.62, -0.24) | 0.00 |
| Maternal height (cm) | 0.01 (0.00, 0.02) | 0.08 |
| Maternal occupation | | |
| Unemployed | reference | - |
| Employed/student | 0.20 (0.00, 0.39) | -0.04 |
| Disease during the last month | | |
| No | reference | - |
| Yes | -0.18 (-0.27, -0.10) | 0.00 |

**Table 2**
**Adjusted effect of the Navarro Waste Disposal Site on growth indices stratified by proportion of life**
**time living in the area and p values for interaction terms**

| Z score | All children | Proportion of lifetime in the study area | | P value |
|---|---|---|---|---|
| | | <50% | >50% | |
| WHZ [a] | -0.16 | 0.02 | -0.18 | 0.48 |
| | (-0.34, 0.00) | (-0.40, 0.45) | (-0.38, 0.00) | |
| HAZ [b] | -0.06 | 0.37 | -0.12 | 0.05 |
| | (-0.31, 0.17) | (-0.18, 0.92) | (-0.39, 0.15) | |

a.  Adjusted by age, maternal height and occupation and disease during the last month
b.  Adjusted by age, maternal height, paternal education level, social security affiliation and access to public services

0.31; 0.17). These estimates did not vary when stratifying by children below and above 24 months of age.

Evaluation of heterogeneity of NWDS effects according to the proportion of lifetime exposure (Table 2) shows that, after adjusting by other potential confounders, exposed children who have lived >50% of their life in the study area tend to have lower Z scores when compared to the control group (WHZ difference = -0.18 and HAZ difference= -0.12), while this effect is not seen among children recently moved into the study area (<50% lifetime). Inclusion of interaction terms in the multivariate model showed that the effect of NWDS in HAZ is heterogeneous depending on the proportion of

lifetime living in the neighbourhood (p=0.05).

To evaluate the role of acute morbidity (i.e.; respiratory disease during follow-up) in the association between NWDS exposure and growth scores, we similarly stratified and tested for interaction effects. Table 3 shows average adjusted difference of Z scores between exposed and control groups among those with and without lower and/or infectious respiratory symptoms. Our data suggest a trend toward larger effect of exposure to NWDS among children with symptoms of disease than among asymptomatic children, and it is more apparent in WHZ (p=0.08). Additional analysis for diarrhea during follow-up showed no interaction (data not shown).

**Table 3**
**Adjusted effect of the Navarro Waste Disposal Site on growth indices stratified by occurrence of respiratory disease during follow-up and p values for interaction terms**

| Z score | All children | Respiratory disease during follow-up | | P value |
| | | No | Yes | |
|---|---|---|---|---|
| **WHZ**[a] | -0.16 | -0.11 | -0.21 | 0.08 |
| | (-0.34, 0.00) | (-0.32, 0.09) | (-0.42, 0.00) | |
| **HAZ**[b] | -0.06 | -0.10 | -0.13 | 0.35 |
| | (-0.31, 0.17) | (-0.35, 0.15) | (-0.44, 0.18) | |

a. Adjusted by age, maternal height and occupation and disease during the last month
b. Adjusted by age, maternal height, paternal education level, social security affiliation and access to public services

## DISCUSSION

This cohort study evaluated the impact of inhabiting near a solid waste disposal site on the weight-height growth of children 0-3 years of age. During follow-up, children of the exposed group had on average a lower WHZ score when compared to a control group (difference= -0.16; p=0.06), after adjusting by children age, maternal height, mother´s occupation and occurrence of disease during the previous month.

In particular, it is of interest to note that exposure to NWDS reduced WHZ score independently of acute disease occurrence. Furthermore, the effect of NWDS tend to be larger among children with acute respiratory disease (difference= -0.21) than in those not reporting respiratory disease (difference= -0.11), which better suggest a biological interaction between the direct effect of pollutants and disease.

Although in other studies respiratory disease has not been associated with alteration on physical growth, pollution and environmental factors have showed association with an increase of respiratory disease[15,16]. It is possible that exposure to these environmental factors causes children to have more severe respiratory symptoms and it ends up slowing their growth.

The fact that WHZ is more rapidly affected after acute exposures than HAZ, which usually needs prolonged or repeated exposures[17,18], probably explained why the last score was not found associated to NWDS exposure in the whole study population during this six-month follow-up period. However, it is highly suggestive of chronic effects in growth to find that HAZ is observed

diminished by exposure to NWDS among those residing >50% of their lives in the study area.

Measurement of air quality in this study area has shown that benzene levels are higher in the exposed area when compared to the control[19]. Given that benzene has been associated with immunologic and hematological effects[20], we hypothesized that long-term exposure to benzene may have an impact on children growth.

Studies evaluating landfill site effects on children physical growth are scanty. A prevalence study made in children living near a water channel highly polluted by solid waste disposal, the Love Chanel in New York[6] found a significant reduction in percentiles of height for age, among children who have lived around that site >75% of their life, even after adjusting for variables such as socioeconomic conditions and parental height. Other studies have searched for association between contamination and growth using crude measurements of height and weight. In Germany, a prospective study found a significant association between higher blood values of dichlorodiphenyl dichloroethene (DDE) and polychlorinated biphenyls (PCBs), two chemical compounds found in solid waste disposal sites, and a reduction of height (1.8 cm, p<0.05) among girls[13]. Another prospective study made in preadolescents evaluated the impact of air quality in height gaining, and found a reduction of 1.5 cm in height in the area with higher levels of $SO_2$ and particulate material after adjusting for confounding variables[12].

In this study exposure to the waste disposal site was ecologically defined, however the prospective cohort design made possible to measure children mobility and

reassured individuals stayed in the study area >80% of time during follow-up. The observed low mobility was expected to be found at this age range and helped to reduce exposure misclassification.

Measurement of multiple covariates strengthened our conclusions by making possible to adjust for known confounding factors. It is reassuring to find in our analysis that poor socio-economical conditions such as lack of social security and low access to public services were, as expected, associated with low growth scores. Controlling for these factors in the multivariate analysis did not eliminate the effect of NWDS.

Main limitations of our study are the relatively short time of follow-up, which limited capacity to further evaluate chronic effects, and the absence of nutritional intake measurements. We adjusted for a complete set of socio-economical covariates expecting to estimate the direct effect of NWDS exposure independently of nutritional intake. Furthermore, given that in the setting of this study the group exposed to NWDS had better socio-economical conditions than the control group, any residual confounding is probably contributing to under-estimate the observed negative effect of NWDS.

In conclusion, our study shows that exposure to this waste disposal site impact children's physical growth, with lower average values of WHZ score. The effect on HAZ score appears to be at long term. Occurrence of respiratory symptoms appears to be related to a greater effect of landfill site on physical growth.

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