Clinical Conditions Associated with Environmental Exposures: an Epidemiologic Study in Two Communities in Juana Díaz, Puerto Rico

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***Background*: A population-based cross-sectional design was used to compare the prevalence of respiratory and general symptoms and of respiratory and heart diseases in two communities of Juana Díaz, Puerto Rico: Guayabal, exposed to particulate matter from quarries and diesel exhaust; and Río Cañas Abajo, which has no such exposure.**

***Methods*: A probabilistic sampling design was used to obtain a representative sample of households and 288 residents of the selected households were interviewed. Adjusted PORs were estimated to assess the relationship between diseases/symptoms and place of residence using logistic regression models. To estimate the parameters of this model, a multilevel approach was used in order to control for potential correlation among residents of the same block.**

***Results*: A higher prevalence of general and respiratory symptoms and of respiratory diseases was observed for residents of Guayabal when compared to Río Cañas Abajo (p<0.05). Residents of Guayabal were more likely to have bronchitis (adjusted POR=5.5; p-value<0.05), nasal allergies (adjusted POR=4.2; p-value=0.01), nasal congestion (adjusted POR=2.9; p-value=0.02), and nausea and vomiting (adjusted POR=8.7; p-value<0.01).**

***Conclusions*: The perception of the community of Guayabal of a higher prevalence of symptoms and health conditions was supported by the present findings. This study provides statistical evidence for the design of an analytical epidemiologic study aimed at evaluating the potential effect of quarrying on adverse health outcomes in the community of Guayabal.**

Key words: Environmental exposures, Quarries, Diesel exhaust, Respiratory diseases, Chronic diseases, General symptoms

It is widely known that particulate matter pollutes the air and it is also associated with a variety of adverse health effects in humans (1-2). These particulates can originate from stationary, mobile, or natural sources and its effects on human health vary depending on its size (3-4). Particulate matter <2.5µm in diameter (fine particulates; PM2.5) and 10µm (coarse particulate; PM10) are strongly associated with respiratory diseases and other adverse health effects in humans, including hypertension and cardiovascular conditions, allergies and inflammatory reactions, and birth defects and deficiencies in child development (1, 5-6). In addition, the elderly and people with emphysema, asthma, and chronic heart and lung diseases are especially sensitive to fine-particle pollution (7-9). Numerous studies have linked elevated particle levels in the air to increased hospital admissions, emergency room visits, and premature deaths (7, 10). Because children's lungs and respiratory systems are still developing, they are also more susceptible than healthy adults to fine particles (11-13).

Rock extraction and truck transportation make quarry operation both a stationary and a mobile source of particulate matter, respectively (14-17). A study from Taiwan found high concentrations of PM2.5 and PM10 in a quarry's neighbor surroundings (14). In Wales, UK, a study found rock particulates between PM2.5 and PM10 and PM2.5 soot particulates from the diesel used in the explosions of a limestone quarry (15). In fact, a major source of soot particulate in quarries is derived from the diesel exhaust of the trucks used to transport the extracted minerals (18). Diesel engines emit a complex mixture of air pollutants, composed of a variety of harmful gases and

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solid materials which include carbon particles and over 40 other known cancer-causing substances (19-20). Also, trucks disperse particulates to the surroundings when they transit the unpaved roads of quarries and from dispersion of their cargo (16-17).

Diesel exhaust and particulates from quarries are suspended in the air, thus exposure to these pollutants occurs whenever a person breathes air that contains these substances. Those living or spending time near the quarries or the roads with the diesel-truck traffic face exposure to higher levels of particulate matter and may face higher health risks (18, 21-22). Multiple studies have shown that particulate matter pollution from quarry operation and diesel exhaust is associated with an increase of several diseases such as heart diseases, respiratory diseases, and several types of cancer (1, 7, 19, 21).

Guayabal is a community in Juana Díaz, Puerto Rico where three limestone and marble quarries are in operation. Here, a single quarry may operate six days per week and have more than 200 diesel-truck trips daily to transport the aggregates (23). A study conducted two decades ago in another quarry located in Puerto Rico documented that, although safety measures were taken in this quarry, dust and particulates reached the surrounding communities (24). Nevertheless, that study did not address the impact of these exposures on the health of the persons living in the communities near the quarry. Residents from Guayabal have expressed concerns about their health status and the presence of air contamination in their neighborhoods (23). Given the rising concern of community leaders regarding the health status of their population and the limited epidemiological information related to health conditions associated with exposure to particulate matter from quarries and truck's diesel exhaust in Puerto Rico, a study that addresses this issue is highly warranted. The aim of this study was to evaluate the association between exposure to particulate matter -from quarries and diesel exhaust- and the prevalence of different clinical conditions and symptoms.

Methods

A population-based cross-sectional study of the non-institutionalized population residing in the communities of Guayabal (exposed to operation of quarries) and Río Cañas Abajo (unexposed community) in the municipality of Juana Díaz, Puerto Rico was conducted during the summer months of 2005. In order to determine the unexposed group, we considered the wind directions in the south region of the Island. Meteorological data suggests that Río Cañas Abajo is not exposed to particulate matter from quarries located at Guayabal or any other known significant source of air pollution due to existing wind directions in this region of Puerto Rico (25).

Working Hypotheses

Given the presence of particulate matter from quarries in Guayabal, we assumed the following hypotheses:

i) The prevalence of general and respiratory symptoms will be higher in the community of Guayabal as compared with Río Cañas Abajo.

ii) The prevalence of respiratory diseases will be higher in the community of Guayabal as compared with Río Cañas Abajo.

iii) The prevalence of chronic diseases (cardiovascular diseases, hypertension, and cancer) will be higher in the community of Guayabal as compared with Río Cañas Abajo.

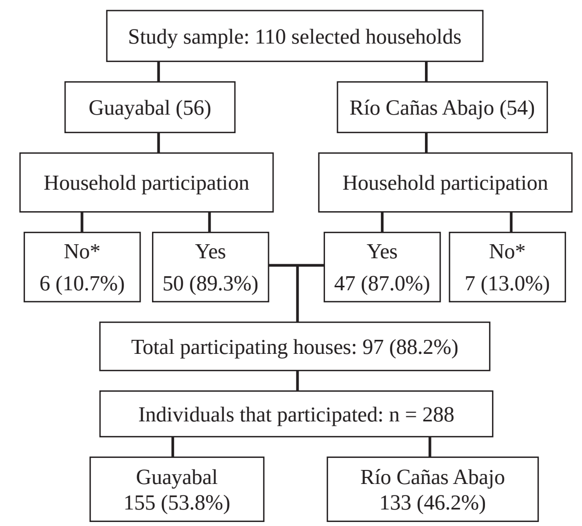
Sampling design

A three-stage cluster sampling design was employed. In the first stage, a systematic selection of household blocks (primary sampling unit), according to the Census 2000, was made proportional to the number of occupied households per block. The second stage consisted of a random selection of a segment of four consecutive households from each selected block. In the third stage, an eligible adult from each household was invited to participate in the study. In order to be eligible for the study, participants must have lived, at least for three months previous to the interview in one of the two communities. In order to answer the interview, household members must have been aged 18 years or older and could not have any impairment that disallowed them from answering a face-to-face interview about the health status of all household members. Information for those younger than 18 years of age was obtained from their parents or legal tutors. Figure 1 shows that 97 of the 110 selected households participated in the study, attaining an overall response rate of 88.2% (89.3% for Guayabal and 87.0% for Río Cañas Abajo). The total number of individuals that participated in this study was 288; 155 (53.8%) from Guayabal and 133 (46.2%) from Río Cañas Abajo.

Data Collection

Seventeen trained interviewers participated in the data collection process. In order to increase the participation rate, residents from selected households were given a letter describing the study procedures one week prior to the interviewer's visit. Households were visited a maximum of three different occasions, in order to increase the contact of participants. After obtaining written informed consent, all eligible subjects completed a structured face-to-face interview. No economic incentive was offered to study participants. The Institutional Review

Board at the University of Puerto Rico Medical Sciences Campus approved the study protocol. All the information collected was stored in an electronic database using Epi-Info (Version 6.04d, 2001) and a re-entry quality control process was performed.



*Reasons for not participating included that persons refused to participate, that no adult was present to provide information, and that nobody was present in the household at the times that the interviewers visited.

Figure 1. Flowchart of participants

Study variables

The main predictor variable of the study was the community of residence, Guayabal versus Río Cañas Abajo. Also, in order to assess their potential confounding effects, we collected information on the following variables: demographic characteristics (age, sex, educational attainment, and block of residence), lifestyle (smoking habits and physical activities), occupation (truck driver or construction worker), pets in the house (dogs, cats, birds, and other animals), and household characteristics (curtains, air conditioners, and rugs). A total of 19 outcome variables were studied including self-reported history (yes/no) of general symptoms (headache, nausea and vomiting, vertigo/dizziness, loss of consciousness, ocular discomfort, and movement difficulties); respiratory symptoms (shortness of breath, nasal congestion, cough, wheezing, and tight chest); respiratory diseases (asthma, sinusitis, bronchitis, laryngitis, nasal allergies, and pneumonia); and chronic diseases (cardiovascular diseases, hypertension, and cancer). For general and respiratory symptoms, we collected information only for symptoms experienceed during the 30 days prior to the interview. For respiratory and heart diseases, we collected information only for conditions diagnosed by a physician during the time period the participants had resided in the community.

Statistical analysis

To describe the study group, contingency tables were used. Initially, Guayabal and Río Cañas Abajo were compared by demographic and lifestyle characteristics and by self-reported general and respiratory symptoms, respiratory diseases, and other chronic diseases. To assess these comparisons, the one-sided p-value was computed to test the homogeneity of proportions using the Chi-square and the hypergeometric probability distributions (Fishers exact test) (26). Only those results showing statistical significance in the bivariate analysis were considered for multivariate analysis. Thereafter, the prevalence of these self-reported conditions were compared throughout the prevalence odds ratio (POR), crude and adjusted, using the logistic regression model ($l\text{ogit}(p) = \beta_0 + \Sigma\beta_i^* X_i$, where X_i are the predictors variables). The procedure to estimate the parameters was performed using a multilevel approach to control for potential correlation among residents of the same household block (27). For each disease and symptom, a one-sided interval was constructed with 95% confidence level to determine the minimum expected value for the POR, as follows: $POR \geq e^{\hat{\beta}_c - 1.64*SE(\hat{\beta})}$, where $\hat{\beta}_c$ is the estimated community effect. If this minimum is greater than 1.0, it implies that there is statistical evidence to conclude that the prevalence of a specific disease (or symptom) was higher in Guayabal as compared with Río Cañas Abajo. All statistical analyses were performed using the statistical package STATA (Version 9.0, College Station, TX, USA).

Results

Significant differences (p-value <0.001) were observed in the mean age of Guayabal residents (34.7 ± 1.9 years) as compared to residents of Río Cañas Abajo (38.8 ± 1.8 years). In addition, the proportion of elderly (65+ years old) was higher in Río Cañas Abajo, whereas the proportion of participants younger than 18 years old was significantly higher (p-value = 0.0484) in Guayabal (Table 1). The gender and educational attainment distributions did not show significant differences (p-value>0.05) among studied communities, nor was the prevalence of current smoking and physical inactivity (p-value>0.05). However, the occupation in both communities showed different patterns (p-value<0.05) with more truck drivers residing in Río Cañas Abajo (6.8%) than in Guayabal (1.9%) and more construction workers residing in Guayabal (10.3%) than in Río Cañas Abajo (3.8%). Despite these differences, the occupation variables were not further analized, due to the small number of those positive responses. Also, pets in the house and household characteristics were not considered as confounder variables given that they did not statistically differ between both communities (data not shown).

Table 1. Demographic and lifestyle characteristics by community

Demographic and lifestyles characteristics	Guayabal n=155 f_i (%)	Río Cañas Abajo n=133 f_i (%)	p-value*
Gender			0.67
Male	73 (47.1)	66 (49.6)	
Female	82 (52.9)	67 (50.4)	
Age (years)§			< 0.05**
<18	48 (31.2)	26 (19.5)	
18-44	48 (31.2)	52 (39.1)	
45-64	44 (28.5)	34 (25.6)	
65 +	14 (9.1)	21 (15.8)	
$\bar{X} \pm SD$	34.7 ± 1.9	38.8 ± 1.8	<0.01***
Educational attainment†			0.66
Sixth grade or less	28 (20.2)	33 (26.0)	
Seventh to ninth grade	16 (11.5)	16 (12.6)	
Tenth to twelfth grade	63 (45.3)	53 (41.7)	
College or higher	32 (23.0)	25 (19.7)	
Occupation††			
Truck driver	3 (1.9)	9 (6.8)	0.04
Construction worker	16 (10.3)	5 (3.8)	0.03
Current smoker††	39 (25.2)	35 (26.3)	0.82
Physical inactivity†	90 (61.3)	80 (60.1)	0.84

* Using Chi-squared distribution for test of Independence
** Exact p-value = 0.0484
*** Unpaired t-test
§ One missing value from Guayabal (n = 154)
† Individuals with 5 years or less were excluded from the analysis (n = 266)
†† Individuals with 18 years or less were excluded from the analysis (n = 213)

Age was considered a potential confounder of the association between community of residence and the outcome variables studied. To control for social differences within and between the communities, the household block was also considered as a proxy of social strata and it was also considered as a potential confounder. Therefore, we compared the self-reported diseases and symptoms between Guayabal and Río Cañas Abajo, adjusting by age as a fixed factor and controlling the intra-social-strata correlation as a random factor in the logistic regression models.

Prevalence for the general symptoms of headache, nausea and vomiting, and vertigo/dizzines were higher in Guayabal than in Río Cañas Abajo (33.5% vs. 18.0%, 16.7% vs. 2.3%, and 11.6% vs. 6.0%, respectively) (Table 2), but only nausea and vomiting was more likely among Guayabal residents (POR = 8.7; 95% CI: ≥ 2.7), after adjusting by age and controlling for the intra-social-strata correlation (Table 3). Among the self-reported respiratory symptoms, nasal congestion had a higher prevalence in Guayabal (29.7%) than in Río Cañas Abajo (12.8%) (p-value<0.001). After adjusting by age and controlling for the intra-social-strata correlation, the odds of nasal congestion was also higher in Guayabal (POR = 2.9; 95% CI: ≥ 1.4) than in the residents of Río Cañas Abajo. No significant differences were observed in the prevalence of the following symptoms between residents of both communities: wheezing, thigh chest, shortness of breath, cough, loss of consciousness, ocular discomfort, and movement difficulties (p-value>0.05).

Table 2. Self-reported prevalence of general and respiratory symptoms, respiratory diseases, and chronic diseases studied by community

Self-reported diseases and symptoms	Guayabal n=155 f_i (%)	Río Cañas Abajo n=133 f_i (%)	p-value*
General symptoms			
Headache	52 (33.5)	24 (18.0)	< 0.01
Nausea and Vomiting†	26 (16.7)	3 (2.3)	< 0.01
Vertigo / Dizziness	18 (11.6)	8 (6.0)	< 0.05**
Loss of consciousness†	6 (3.8)	4 (3.0)	0.47
Ocular discomfort	28 (18.1)	17 (12.8)	0.11
Movement difficulties	10 (6.5)	7 (5.3)	0.33
Respiratory symptoms			
Wheezing	12 (7.7)	7 (5.3)	0.20
Tight chest	17 (11.0)	17 (12.8)	0.32
Shortness of breath	18 (11.6)	13 (9.8)	0.31
Cough	28 (18.1)	16 (12.0)	0.08
Nasal congestion	46 (29.7)	17 (12.8)	< 0.01
Respiratory diseases			
Asthma	11 (7.1)	14 (10.5)	0.20
Sinusitis	19 (12.3)	11 (8.3)	0.13
Bronchitis†	11 (7.1)	2 (1.5)	0.02
Pneumonia†	2 (1.3)	1 (0.8)	0.58
Nasal allergies	26 (16.8)	6 (4.5)	0.01
Laryngitis†	4 (2.6)	1 (0.8)	0.24
Chronic Diseases			
Cardiovascular diseases	9 (5.8)	14 (10.5)	0.07
Hypertension	20 (12.9)	28 (21.1)	0.03
Cancer	2 (1.3)	3 (2.3)	0.86

* One sided test to compare proportion using Normal Distribution
** Exact p-value = 0.0492
† Fisher exact test

Among respiratory diseases, the prevalence of self-reported bronchitis and nasal allergies were statistically different between communities (p-value<0.05); with the prevalence of both nasal allergies (16.8%) and bronchitis (7.1%) being higher in Guayabal than in Río Cañas Abajo (4.5% and 1.5%, respectively). When these comparisons were adjusted by age and controlled by intra-social-strata correlation, both bronchitis (POR = 5.5; 95% CI: ≥ 1.3) and nasal allergies (POR = 4.2; 95% CI: ≥ 1.9) maintained their statistical significance (Table 3). Meanwhile, no differences between communities were observed in the prevalence of the following respiratory diseases in the communities studied: asthma, sinusitis, pneumonia, and laryngitis (p-value>0.05).

Table 3. Prevalence odds ratios (POR) for self-reported diseases and symptoms to assess the community effect

Self-reported diseases and symptoms	POR Crude† (95% CI)	p-value*	POR Adjusted† (95% CI)	p-value*
General symptoms				
Headache	1.9 (≥0.9)	0.17	2.0 (≥0.9)	0.14
Nausea and Vomiting	8.8 (≥2.7)	< 0.01	8.7 (≥2.7)	< 0.01
Vertigo / Dizziness	1.9 (≥0.7)	0.31	2.0 (≥0.7)	0.28
Respiratory symptoms				
Nasal congestion	2.8 (≥1.3)	0.03	2.9 (≥1.4)	0.02
Respiratory diseases				
Bronchitis	5.5 (≥1.3)	<0.05	5.5 (≥1.3)	<0.05
Nasal allergies	4.1 (≥1.9)	0.01	4.2 (≥1.9)	0.01
Chronic diseases				
Hypertension	0.5 (≥0.3)	0.16	0.6 (≥0.3)	0.31

* One sided test (Guayabal prevalence's > Río Cañas Abajo prevalence's)
† Adjusted by sex and controlled by intra-social-strata correlation using a Logistic regression model with random intercept.

Regarding heart diseases, the prevalence of hypertension was actually lower in Guayabal (12.9%) than in Río Cañas Abajo (21.1%) (p-value = 0.03) in the bivariate analysis, although no differences were observed in the prevalence of cardiovascular diseases. Nonetheless, after adjusting for age and controlling the intra-social-strata correlation, no significant difference was observed in the likelihood of hypertension between both communities (p-value>0.05).

Discussion

This is the first epidemiological study that assesses the prevalence of clinical conditions associated with environmental exposures related to quarry operation and diesel exhaust by truck traffic in Puerto Rico. Our data revealed a higher prevalence for the majority of symptoms and diseases studied in the exposed community of Guayabal in comparison with the non-exposed community of Río Cañas Abajo. Multilevel analysis showed that people living in Guayabal were more likely to have nausea and vomiting (adjusted POR=8.7; p-value<0.01), nasal congestion (adjusted POR=2.9; p-value=0.02), bronchitis (adjusted POR=5.5; p-value<0.05), and nasal allergies (adjusted POR= 4.2; p-value=0.01) than those residing in Río Cañas Abajo.

While only a few years ago scientists could not explain the trends in health effects observed through epidemiological studies of particulate matter pollution from a biological basis, there are now multiple hypotheses to describe the mechanisms by which very small concentrations of inhaled particulate matter can induce negative health effects (1). Clinical studies and animal models that mimic human disease have produced several theories about how the physical and chemical properties of particulate matter can produce the cardiovascular and pulmonary changes that contribute to increased illness (1, 28).

The majority of diesel particulate matter is less than 1 µm in diameter and particulates from quarries range from 2.5 µm to 10 µm (1, 14-15). In general, particles 10 µm or less in diameter can be inhaled into the lungs (1). Chemicals adsorbed on particles can dissolve in the fluid lining the airways and then be absorbed into the body (7). Research has shown that, in fact, average life expectancy can be reduced by about 1.5 years, comparing the places with highest and lowest particulate matter levels and a loss of about 14 years of life can be experienced among those people with high particulate matter exposure (7).

General and respiratory symptoms

Although a higher prevalence of all the general symptoms studied was higher in Guayabal than in Río Cañas Abajo, only nausea and vomiting showed statistical significance in adjusted analysis. Our results are consistent with the fact that exposure to diesel exhaust can have immediate health effects. Epidemiological studies and official reports by federal and state agencies have reported that short exposure to particulate matter and diesel exhaust is sufficient to irritate the eyes, nose, throat, and lungs, and may cause headaches, light-headedness, and nausea and vomiting (1, 7, 12).

Our results are also consistent with previous studies (29), given that the majority of the respiratory symptoms studied were also more common in Guayabal than in Río Cañas Abajo. Nevertheless, only nasal congestion was statistically significant in crude and adjusted analysis (p<0.05). Exposure to particulate matter from quarry operation or truck's diesel exhaust increases the risk of adverse respiratory symptoms such as having cough without having a cold, wheezing, and tight chest (7, 21). In addition, exposure to particulate matter is associated with hospitalizations related to respiratory problems (10) and to children's school absences due to respiratory and other diseases (30). Children whose schools are exposed to quarries have a higher possibility of having cough without having a cold in comparison to those whose schools are not exposed (21). Particulate matter has an adverse effect on the respiratory health of children even when their levels are below those established by law (31) and is associated with hospitalizations related to respiratory problems (10).

Respiratory diseases

The prevalence of nasal allergies (16.8%), bronchitis (7.1%), and sinusitis (12.3%) observed in our study were higher among the residents of Guayabal than the prevalence's reported in Puerto Rico (nasal allergies = 5.0%, bronchitis = 4.2%, and sinusitis = 7.7%) (32). Meanwhile, the prevalence of these conditions in residents of Río Cañas Abajo was similar or lower than the overall prevalence in Puerto Rico. Nevertheless, only having nasal allergies was statistically significant in the multivariate model showing a higher POR (2.9) for Guayabal residents when compared to those residing in Río Cañas Abajo. Our findings are consistent with other epidemiological studies that have shown a higher possibility of suffering from these respiratory diseases due to the exposure of particulates in the air (12, 21) among people who reside near quarries. This association can be partially explained by the fact that diesel exhaust is a complex mixture of thousands of gases and fine particulates that contain nitrogen oxides that damage lung tissue, lower the body's resistance to respiratory infection, and worsen respiratory diseases (29).

Worldwide, the prevalence of allergies has risen near 30% and one of the possible causes is the rise of $PM_{2.5}$ from motor vehicle emissions (33). Preliminary evidence suggests that diesel particulate matter exposure may facilitate development of new allergies (28, 34). Also, it has been documented that people who live near areas with high transit of heavy trucks have a higher incidence of nasal allergies than those who live in areas with less truck traffic (33). For bronchitis, a study from the World Health Organization found that people exposed to $PM_{2.5}$ and PM_{10} particulates have 34% more possibility of having the disease (35). In addition, children whose schools are exposed to quarries have a higher possibility of having cough without having asthma and bronchitis in comparison to those whose schools are not exposed (21). In fact, by age 18, children exposed to higher levels of PM2.5, NOX, acid vapor, and elemental carbon (all products of fossil fuel combustion, especially diesel) are five times more likely to have underdeveloped lungs compared to teenagers living in communities with lower pollutant levels (13).

Chronic diseases

After adjusting for age and controlling for the intra-social-strata correlation, no significant differences (p-value>0.05) were observed in the prevalence of cardiovascular diseases and cancer among residents of Guayabal and those of Río Cañas Abajo. Contrary to our findings, several studies have reported that exposure to particulate matter is associated with an increase of both diseases (36-38). Also, it has been demonstrated that exposition to particulate matter and diesel exhaust leads to changes in cardiac rhythm (39-40) and increases the risk of experimenting early symptoms of myocardial infarction (41-42). Elderly people living near major roads have almost twice the risk of dying from cardiopulmonary causes (43-44) and fine particulate matter from mobile sources accounts for three times the mortality as from coal combustion sources (45). Particulate matter is also a contributing factor to hospital admissions and emergency room visits and lost work days for cardiopulmonary causes (46-48). Nevertheless, we did not find any difference for physicians and emergency room visits between both communities (data not shown).

Study limitations and strengths

Among study limitations, the cross-sectional design used in this study limits our ability to establish a temporal sequence between the environmental expositions and the diseases and symptoms studied. Also, the level of particulate matter exposition for each household and between both communities was not measured. Although community of residence was used as a proxy of environmental exposure, the lack of accurate measurement of exposure to particulate matter among study participants from both communities could bias the associations found in this study towards the null hypothesis (no association), given that non-differential misclassification occurred (49). An underestimation of the magnitude of association between community of residence and the diseases studied could also exist, given that we collected information only from diseases diagnosed by a health professional, thus, people with symptoms but with undiagnosed diseases were considered as non-diseased in our analysis, increasing the possibility for misclassification bias in our study. In addition, health conditions were self-reported and could not be confirmed by medical record review. Finally, the limited small sample size of our study and the fact that the prevalence of some of the conditions studied is somewhat low in the general population, such as cancer, could have impacted the power of our study, and thus our ability to find an association between community of residence and several of the outcomes under study.

Despite the previous limitations, our study has important strengths. First, the cross-sectional design with a random sample provides us with good external validity and thus generalization of study results can be extended to residents of both communities. In addition, randomization of households from both communities proved to be effective, as it resulted in comparable study populations in terms of demographic and lifestyle characteristics. Also, we had a high participation rate (88%).

Public policy actions

Public policy actions should be supported and enforced by Puerto Rico's Department of Environment and Natural Resources and the Department of Health on behalf of these findings. The Department of Environment and Natural Resources should implement stricter rules for the approval of permissions for quarry operation in Puerto Rico and should enforce procedures that guarantee a lower impact of particulate matter in the communities surrounding quarries during the rock extraction processes. Meanwhile, the Department of Health of Puerto Rico should develop public health programs aimed at reducing the health disparities observed in these communities. Further action to monitor the health status of Guayabal residents and other neighboring communities exposed to quarry operations should also be taken into account.

Conclusion

In conclusion, our results support the community's perception that there is a high likelihood of various general and respiratory symptoms, as well as respiratory diseases in Guayabal, Puerto Rico. Among recommendations, future analytic population based studies should aim to better quantify the environmental exposures that these quarries represent for the residents of Guayabal and other adjacent communities, including the presence of dust and diesel particulate in households, schools, and workplaces. This is of particular relevance because the reports of the environmental impact of each of Juana Díaz's quarries that are available through the Puerto Rico's Department of Natural Resources are provided by the quarries themselves as a requirement for the operation permits. Thus, the real environmental impact of this industry to adjacent communities is still unknown. Future studies should also consider biological markers of disease, in order to better classify persons as diseased or non-diseased. In addition, they should attempt to address the interactions of particulate matter with other pollutants such ozone and allergens, on disease occurrence. Ours and future population-based studies that further elucidate the environmental impact of quarries on the health of the people in Puerto Rico are highly warranted, as more than a dozen quarries currently operate on the island.

Resumen

Se utilizó un estudio transversal para comparar la prevalencia de algunos síntomas generales y respiratorios y de enfermedades respiratorias y del corazón en dos comunidades de Juana Díaz, Puerto Rico: Guayabal, expuesta a material particulado de canteras y de emisión de diesel; y Río Cañas Abajo, que no tenía esa exposición. Para obtener una muestra representativa de las viviendas, se utilizó un diseño probabilístico de muestreo, donde fueron entrevistados 288 residentes de las viviendas seleccionadas. Se estimaron los POR ajustados para medir la relación entre padecer de algún síntoma/enfermedad y el lugar de residencia con modelos de regresión logística. Para estimar los parámetros de este modelo, su utilizó un modelo multinivel para controlar posibles correlaciones entre residentes del mismo bloque. Se observó una mayor prevalencia en los síntomas generales y respiratorios y en las enfermedades respiratorias de los residentes de Guayabal al compararlos con los residentes de Río Cañas Abajo ($p<0.05$). Los residentes de Guayabal tienen mayor posibilidad de padecer de bronquitis (POR=5.5; p-value<0.05), alergias nasales (POR=4.2; p-value=0.01), congestión nasal (POR=2.9; p-value=0.02) y naúseas/vómitos (POR=8.7; p-value<0.01). Nuestros resultados confirman las preocupaciones de los residentes de Guayabal sobre una alta prevalencia de síntomas y condiciones de salud en su comunidad. Este estudio provee evidencia estadística para el diseño de un estudio epidemiológico analítico que determine el efecto de la operación de las canteras y el desarrollo de condiciones de salud en la comunidad de Guayabal.

Acknowlegments

We acknowledge the residents of Juana Díaz, Puerto Rico who participated in this study. Also, Mr. Jorge Ariel Torres, community leader of Guayabal, for his commitment to the health of the people of Guayabal and for his continued support in the development of this project. In addition, we thank all members of the community-based organization CORENA for their support in the identification of households. We recognize Dr. Imar Mansilla and Dr. Carlos Rodriguez from the Department of Environmental Health, Graduate School of Public Health, University of Puerto Rico, for their conceptual contributions to the study. This work was presented as an oral presentation in the American Public Health Association Annual Meeting (November 2006 at Boston, MA) and received the Student Award from the Epidemiology Section. Research infrastructure of this project was partially funded by NIH NCRR RCMI Grant G12RR03051.

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