Indoor Air Quality Monitoring of Communities Surrounding a Coal-Fired Power Plant in Pagbilao, Quezon

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ABSTRACT

Objectives. The study evaluated the quality of indoor air in households surrounding a coal-fired power plant in Pagbilao, Quezon and its impact to the residents in these communities.

Methods. The researchers used a quantitative approach and gathered both primary and secondary data from the Province of Quezon, Municipalities of Pagbilao and Padre Burgos and 12 other barangays from January to June 2008. A household survey was conducted to obtain the health and socio-demographic characteristics of the respondents. Likewise, indoor air quality surveys, respiratory health profiling and pulmonary function tests were done. Indoor air quality monitoring measured eight hour levels of particulate matter-10 (PM_{10}) in "near" and "far" barangays and sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) in two primary impact barangays as indicated in the environmental impact assessment of the power plant.

Results and Conclusion. Results showed that there is no significant difference ($p = <0.05$) in the eight-hour average of indoor PM_{10} in "near" and "far" barangays. The monitoring results for SO_2 and NO_2 are below the ambient air quality standards. The results of respiratory profiling and pulmonary function testing revealed that the significant risk factors for respiratory symptoms and pulmonary function parameters are generally demographic characteristics such as sex, height and weight. However, cigarette smoking and indoor PM_{10} levels, which came out as significant risk factors for wheezing and the predicted forced expiratory volume at 1 second (FEV1), respectively, reflect the environmental exposure of children inside their homes.

Key Words: indoor air quality, environmental illnesses, tobacco smoke pollution, respiratory diseases

Introduction

The coal-fired power plant in Pagbilao, Quezon has been operating since 1993. Several environment and health monitoring studies were conducted in the site in accordance with the requirements of the environmental compliance certificate (ECC) issued by the Department of Environment and Natural Resources. After the release of the ECC in 1992, a baseline health study was immediately conducted in 1994 to serve as a reference for future health monitoring studies. The previous studies, which were undertaken by the Health Safety and Environment Management Consultancy, Inc. (HSEMCI), focused on the environmental health conditions of Pagbilao Grande Island and nearby areas in the years 1998 and 2003.

The results of the environmental health study done in 1998 showed that the mean PM_{10} level of 196 ug m^{-3} exceeded the acceptable limit by 300 times. The major sources of indoor PM_{10} are cooking fuel (wood or charcoal), gas lamps used for lighting and road dusts since all barangay roads are not paved. Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) levels are well below the health standards. The respiratory health of children living around the coal-fired power plant followed the typical respiratory profile of children in poor rural communities in the Philippines characterized by a high prevalence of upper respiratory tract infection and other illnesses related to the respiratory system. Wood and sawdust used as cooking fuel have adverse effects on the respiratory health (FEV1) of children in the study communities. Other health determinants are sex of the child (female sex) and chronic malnutrition (children with lower weight for their height). A significant number of children have low pulmonary function FEV1 values. Low FVC values were likewise seen among children in most of the study communities. The predictors of abnormal FVC were sex and height with the females and shorter children at a disadvantage. Also, children in barangays near the plant and those in households which practice open burning of garbage have higher odds that they could have abnormal FVC.

In 2003, the prevalence of the respiratory symptoms and illnesses in the past year have declined compared to the 1998 survey. However, the doctor-diagnosed asthma for the survey year 2003, has considerably increased. In all study barangays, there was a considerable increase in the number of children with FVC less than 80% of predicted compared to the 1998 survey. For FEV1, a slight decrease was noted.

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Comparing with the 1998 study results, the 2003 results indicate some improvement in terms of the mean PM_{10} level.

The provision of environmental health programs like the Carbon Sink Initiative by the power plant remain a valuable component towards the fulfillment of the requirements set forth by the government agencies. This environmental health monitoring study provides the foundation for the implementation and strengthening of the environmental and health programs directed towards the existing communities in Pagbilao Grande Island and neighboring areas. Moreover, it aims to provide information regarding the quality of indoor air in the barangays surrounding the coal-fired power plant and its impact on health.

Based on previous studies, coal-fired power plants are significant sources of air pollutants such as respirable particulate matter (PM) and gases such as nitrogen oxide (NOx) and sulfur oxide (SOx). Exposure to these air pollutants has been associated with increased morbidity and mortality due to cardiopulmonary diseases, lung cancer and other respiratory illnesses.[1] Studies have shown that on a global scale, there are 210,000 deaths annually resulting from air pollution due to coal combustion.[2] The groups that are most susceptible to the effects of these air pollutants are children, the elderly and those with pre-existing respiratory and cardiovascular diseases.[3]

The air pollutants can penetrate indoors and significantly alter the quality of indoor air. According to the Occupational Safety and Health Administration (OSHA), indoor air quality can affect the health of people residing or confined in a particular space and can suffer from both long-term and short-term diseases.[4] The usual symptoms associated with poor indoor air quality are "headaches, fatigue, trouble concentrating, and irritation of the eyes, nose, throat, and lungs".[4] Moreover, exposure to the indoor air pollutants depends on factors such as ventilation, temperature, humidity, contaminants, and other activities that occur within or adjacent to the area.[4]

Significance of the Study

Data generated from the study provides the municipal and barangay health officials with useful information regarding the quality of air in the areas surrounding the power plant and its impact on health. The information can be used as the basis for amendments of existing and/or creation of new health programs and policies for the present and the near future. The knowledge on the status of air quality paves the way for preventive and routine health programs to ensure that the communities near the power plant are healthy.

Objectives

This study aims to fulfill the following objectives:

- To describe the community health profile of municipalities and barangays surrounding the coal-fired power plant;
- To determine exposures of selected households to indoor air pollutants such as PM_{10} in "near" and "far" barangays and NO_2 and SO_2 in two impact barangays;
- To determine the association between PM_{10} levels and selected exposure variables such as location, type of cooking fuel used, location of cooking facility, presence of smoker, location of household relative to the main road, ventilation and housekeeping; and
- To assess the respiratory health profile of 6-10-year-old children in study households and determine the risk factors associated with this profile

Materials and Methods

Study Design

The researchers used a quantitative descriptive research approach, which enabled the collection of numerical data that adequately describes the environmental health conditions in the area.

Study Sites

The study covered barangays "near" and "far" from the coal-fired power plant. The study barangays were categorized as "near" barangays and "far" barangays, representing their relative location to the power plant as specified in the Environmental Impact Statement. The barangays located near the power plant are Ibabang Polo, Ilayang Polo, Kanlurang Malicboy, Lipata and Tulay Buhangin while Alupaye, Bantigue, Daungan, Mapagong, Silangang Malicboy, Rizal and Sipa are located far from the power plant.

Study Population

The household survey included 1700 households in the 12 study barangays. All of the households in Ibabang Polo and Ilayang Polo were surveyed to enable comparison with the data gathered in 2003. As for the other study barangays, the following criteria were considered in the selection of households:

1. There should be at least one child between the ages of six to 10 years old residing in the household during the period of the study;
2. The household should have been in the study area for a period of not less than two years during the time of the study; and
3. The household should have given their consent to participate in the study.

These three qualifying factors were also used to identify the respondent households for the respiratory health monitoring component of the study. Apart from the respiratory health of the community, the survey aimed at gathering pertinent information regarding the respondents' socio-economic and demographic characteristics and health profile. Other proxy indicators for indoor air quality, such as

cigarette smoking, type of cooking fuel used and practices of burning garbage and agricultural wastes were also obtained.

For respiratory health profiling and pulmonary function testing, about 25 percent of qualified households based on the inclusion criteria, or 370 households and 370 children aged six to 10 years old, participated in the respiratory health survey and spirometry, respectively. In cases where more than one child aged six to 10 years old reside in the household, the older child was asked to undergo the pulmonary function testing. Informed consent was obtained prior to the conduct of respiratory health profiling and pulmonary function testing.

Data on the medical history of children regarding respiratory signs and symptoms experienced in the past year were collected together with data on possible exposures (cooking fuel used, cooking duration, location of the house, parental smoking, etc.). Respiratory function and capacities were determined using a field spirometer, which was regularly calibrated for the purpose of the study. The aim of the spirometry was to obtain a quantitative assessment of the respiratory health profile of the study children.

For indoor air quality monitoring, about 50% (n=181) of the households that participated in the respiratory health monitoring were purposively sampled. The sampling was based on household location with reference to the power plant, the cooking fuel used, the smoking rate of household members, house ventilation, roadside location of households and other exposure factors. A sub-sample of households were selected from the 181 households monitored for PM_{10} in "near" barangays to participate in the sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) monitoring. Sulfur dioxide and NO_2 measurements were not performed in the "far" barangays.

Parameters

The household survey obtained socio-economic and demographic characteristics of study households, health profile and access to water supply sanitation facilities and electricity. Socio-economic and demographic variables included age, sex, education, income and expenditures, employment and sources of income, and housing conditions among others. Health information on members of study households including history of medical illness, immunization, health maintenance and improvement activities, access to health services, and hygiene practices were likewise studied. Other proxy indicators for indoor air quality such as cigarette smoking, type of cooking fuel used and practices of burning garbage and agricultural wastes were also obtained.

Statistical Analysis

Using Microsoft Excel and Epi Info softwares, descriptive analysis was performed to determine the indoor air pollutants levels and the respiratory profile of study participants. To determine the significant correlates, multiple logistic regression was performed in STATA for five outcomes, (1) PM_{10} levels; (2) frequent cough; (3) wheezing; (4) FVC/PFVC <80% predicted; and (5) FEV1/PFEV1 <80% predicted.

Selected exposure variables such as gender, weight, height, location near main road, housekeeping, and presence of smoker were considered in the modelling. Indoor PM_{10} level was considered an exposure factor for the four outcomes and was therefore included in the models. The level of significance was set to p-value ≤0.05. Confidence interval estimates of the odds ratio for the significant correlates of the five outcomes were derived from the final models.

Results and Discussion

Health and Environmental Profile

Municipalities of Pagbilao and Padre Burgos. The study areas included the Municipalities of Pagbilao and Padre Burgos and eight barangays in Pagbilao and four in Padre Burgos. For Pagbilao, the leading causes of morbidity, which were consistently on the top of the list from 2003 to 2007, were communicable in nature, namely respiratory infections, skin disease and gastrointestinal diseases. Other infectious diseases that were among the leading causes of illness were parasitism, TB respiratory, and pneumonia. Many of these infectious diseases were associated with environmental factors, such as poor access to water supply and sanitary toilets, overcrowding, and poor hygiene practices. The non-infectious diseases that were included in the list were wounds, hypertension, and asthma.

When it comes to mortality, most of the reported causes were generic, such as cardiac arrest, heart failure, and multi-organ failure, which prompted the researchers to create a category for reportable causes of death. For the present study, the leading causes of death were non-communicable diseases (cerebrovascular accident and cancer) and communicable diseases (pneumonia). The major contributors of mortality reported in 1998 remained almost the same until the 2003 study. From 2003 to 2007, the statistics and findings remained consistent. When comparing the mortality data for Padre Burgos and Pagbilao, it was noted that the health profiles for the two areas were the same but the former presented a microcosm of the health statistics found for the latter. The data depicted a typical health profile of a developing rural community.

Barangay health profile

The health profile of the study barangays shows similar profile with that of their respective municipality. The causes of morbidity in the study barangays were mostly infectious, except for wounds, hypertension, gastritis, arthritis, and asthma. Likewise, all of the study barangays had reported cases of acute respiratory infections, skin diseases, diarrhea, and parasitism. In comparison to the 2003 study, the same

diseases that caused morbidity among the members of the barangays were found in the present study. As for mortality, cardiovascular arrest, myocardial infarction, pulmonary tuberculosis, cancer, chronic obstructive pulmonary diseases, pneumonia, and gunshot wounds remained the primary diseases that served as the causes of death in the barangays.

Demographic Profile of Respondents

Socio-economic Survey. The respondents to the socio-economic survey were mostly the spouses of the household heads (61.9%), while household heads that responded constituted 33.5 percent. Only 3.2 percent of respondents were the adult children and only one (1.3) percent are the other members in the household. Majority (85%) of the respondents were females. Majority of respondents were the spouses of the household heads, of which the females were a large majority at 99 percent, with a few males at only 3 percent.

Respiratory Health Profiling. More than half (57%) of the study children are either first or second born and almost a third are 3rd or 4th born (Figure 1). There are, on the average, 3.8 children (0-10 years old) and 1.3 children aged 6-10 years in the family of the study child. The total number of study children is 370 aged 6-10 years old and their average age is 8.7 years.

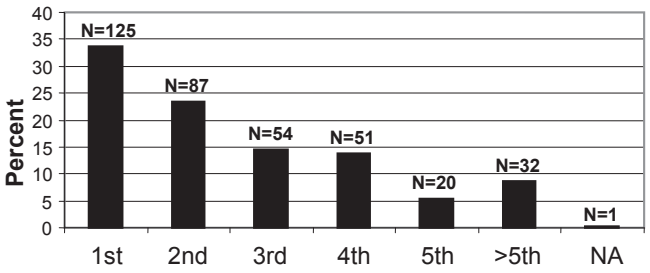

Figure 1. Birth hierarchy of study children, 2008.

Socio-economic Profile

Household size. A more accurate estimate of the household size can be computed from Ibabang Polo (4.8) and Ilayang Polo (4.4) because a complete census was done for both barangays. All the other study barangays had a household size of more than five, which is the average.

Crowding index. The crowding index for Ibabang Polo and Ilayang Polo were 3.7 and 3.6, respectively. An estimated 66 to 60 percent were considered overcrowded because their reported crowding index exceeded the cut-off recommended in previous health studies, which was 2.5. In terms of space available, more than 70% of the households in Ibabang Polo and Ilayang Polo offered insufficient space per person, according to the recommendation of the Department of Health for suburban areas, which is 12 sq.m. per individual. The crowding index provided close estimates, indicating that, on the average, majority of the households were overcrowded. The data from these two barangays, likewise, reflected a better picture of actual crowding profile in the study areas since a complete census was conducted in these barangays.

Access to electricity. Only 48% of the households in Ibabang Polo and 43% of the households in Ilayang Polo have access to their own source of electricity while 20% in Ibabang Polo and 35% in Ilayang Polo do not have any access to any alternative sources of electricity. This presents a fairly poor access to electricity in Ibabang Polo and Ilayang Polo and this profile even deteriorated when compared with the 2003 results**.** As a result, tapping into the neighbor's source of electricity became a common practice among the households that do not have their own source of electricity. For those households that do not have access to alternative sources of electricity, the most common source for lighting is the *gasera/lampara***.**

Indoor Air Monitoring

The indoor air monitoring measured eight hour levels of particulate matter-10 (PM_{10}) in the "near" and "far" barangays and sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). The SO_2 and NO_2 measurements were only done in two "near" barangays including Ibabang Polo and Ilayang Polo since these were the barangays that are primarily affected by power plant operations, as indicated in the environmental impact assessment report for the power plant.

Results of indoor air monitoring. The levels of indoor air pollutants obtained from the monitoring activity for the "near" and "far" barangays are summarized in Tables 2 and 3, respectively. The 8-hour measurements were adjusted to 24 hours for the purpose of comparing these with the Philippine ambient air quality standards. However, it should be noted that indoor exposure would be higher than ambient (outdoor) exposure because more time is spent indoors, particularly for children, and dispersion of pollutant indoors would be slower than in the ambient atmosphere.[5] In the absence of non-occupational indoor standards, comparisons were made using the national ambient air quality standards. The 24-hr standard for PM_{10} in ambient air is 150 $\mu g\ m^{-3}$ and the annual standard is 60 $\mu g\ m^{-3}$. The 24-hr ambient standard for SO_2 is 180 $\mu g\ m^{-3}$ and 150 $\mu g\ m^{-3}$ for NO_2.

The SO_2 and NO_2 levels are below the ambient standards. There is no significant difference in the 8-hr average of indoor PM_{10} in the "near" barangays and the "far" barangays. Although the indoor levels are lower than the 24-hr ambient standard for PM_{10}, it should be noted that dispersion of indoor pollutants is relatively lower than that in the ambient air. Thus longer duration of exposure by household members to this air quality poses a higher risk to their health and, most especially, for the children. Furthermore, this condition is aggravated by the fact that a) 90 percent of the study households use biomass fuel (wood or charcoal) for cooking; b) majority (67%) of them cook inside the house; and c) more than half (54%) of the households had at least one member who is a smoker.

The most commonly cited health impacts of long-term exposure to particulate matter are cardiovascular and respiratory disease and cardiovascular mortality.[6,7]. Nitrogen dioxide is considered an airway irritant. The cohort study of Nesas et al. (1991) showed increased incidence of respiratory symptoms among children 7-14 years old as a result of exposure to NO_2 levels more than 38μg/m^3.[8] According to American Toxic Substances and Disease Registry, short-term exposure to elevated levels of SO_2 can lead to breathing difficulties and severe airway obstruction. Long-term exposure, on the other hand, diminishes lung function. Moreover, asthmatics have increased susceptibility to SO_2 at concentrations ranging from 0.2 to 0.5 ppm.[9]

Association Between PM_{10} levels and Exposure Variables. Table 4 shows that there are no significant correlates of PM_{10} levels. In the regression analysis, only three variables were retained by the model. However, these three do not have significant association with PM_{10}. It can be surmised that the indoor pollutant levels are almost the same between the exposure variables that significant variability cannot be established or the sample size is too limited.

Respiratory Health Profile of Study Children

There were two data collection methods used for establishing the respiratory health of children, namely, the respiratory health questionnaire and the pulmonary function testing (PFT). A total of 370 respondents and corresponding number of children participated in the study. Respondents were interviewed and lung function tests were conducted among the respondent children. Majority (80%) of the respondents were mothers.

Cooking fuel. The primary cooking fuel used by the study child's household was wood/charcoal (85.6%) while only a minimal proportion of 13.5% used LPG (Table 1). Some 66% of these households cook inside the house almost all the time and the rest cook outside the house.

Table 1. Cooking Fuel Use among Study Households, 2003 v 2008

Cooking fuel used	2003 N=2225 n(%)	2008 N=1700 n(%)
Wood/charcoal	1421 (63.9)	1316 (77.4)
LPG	945 (42.5)	185 (10.9)
Wood	431 (19.4)	216 (12.7)
Kerosene	40 (1.8)	5 (0.3)
Others	22 (0.1)	4 (0.2)

Smoking exposure. The usual caretaker of the study child was the mother (89.7%) and only 4.3% of them were current smokers. Among the mothers who smoked, about 79% smoke less than 1 pack per day and 42% of them smoked in front or near the child. Despite the small percentage of mothers who smoke, the child could still be exposed to second hand smoke from the child's father and other household members. Some 44.6% of fathers were current smokers and 54% of these father-smoker consumed one to two packs of cigarettes per day. Almost half (48%) of these fathers smoked in front or near the study child.

Table 2. Levels of Indoor Air Pollutants in Near Barangay Households, 2008

Indoor Air Pollutant	Ibabang Polo	Ilayang Polo	Kanlurang Malicboy	Lipata	Tulay Buhangin	Total
PM_{10},ug/cu.m.						
N	73	30	11	5	6	125
Mean 8-hr	159	148	133	150	153	149
Mean 24-hr	110	102	92	104	106	103
S.D.	141	118	84	37	97	95
Range	83 - 752	83 584	78 - 333	83 - 167	83 - 333	83 – 752
SO_2, ug/cu.m.						
N	20	9	3	2	2	36
Mean 8-hr	0.02	0.02	0.01	0.04	0.01	0.02
Mean 24-hr	0.014	0.014	0.007	0.028	0.007	0.013
S.D.	0.008	0.005	0.002	0.04	-	0.013
Range	0.01 - 0.04	0.01 - 0.02	0.01 - 0.02	0.01 - 0.07	0.01 - 0.01	0.01-0.07
NO_2, ug/cu.m.						
N	21	9	6	7	1	44
Mean 8-hr	26	26	25	26	26	25.8
Mean 24-hr	18	18	17.3	18	18	17.9
S.D.	0.00E+00	0.00E+00	1	0.00E+00	-	
Range	26 - 26	26 - 26	24 - 26	26 - 26	26 - 26	24-26

24-hr standards: PM_{10}-μg/ncm; SO_2=180μg/ncm; NO_2=150μg/ncm

Table 3. Levels of Indoor Air Pollutants in Far Barangay Households, 2008

Indoor Air Pollutant	Alupaye	Bantigue	Daungan	Mapagong	Rizal	Silangan	Sipa	Total
PM_{10},ug/cu.m.								
N	8	8	10	10	5	10	5	56
Mean 8-hr	104	156	175	125	157	119	184	146
Mean 24-hr	72	108	121	86	109	82	127	101
S.D.	59	94	61	59	83	58	92	72
Range	83 - 250	83 - 334	83 - 250	83 -251	83 -286	83 - 251	83 -251	83 -334

Table 4. Association between indoor PM_{10} and selected household variables, 2008

Variables	Odds Ratio	95% confidence interval	p- value
Near main road	0.82	1.39-1.76	0.61
Housekeeping	0.79	0.45-1.36	0.39
Presence of smoker	1.97	0.92-4.24	0.08

A summary on the potential sources of exposure of the study child to cigarette smoke compared with the results of the 2003 study is shown in Table 5. Compared to the 2003 study, which had 53.6% of the fathers smoking and 5% of the mothers smoking, this study showed some improvement in terms of both parents' smoking practices. Passive smoking is a very important risk factor in the causation of several obstructive lung diseases, such as asthma attacks and bronchitis episodes among children.[10]

Respiratory Symptoms and Past Illnesses of Study Children. From the child respiratory survey, a little more than one-fourth (26.7%) had frequent cough, 8.4% experienced chest tightness and 11% had wheezing. In terms of frequency of occurrence, some 52% of children with frequent cough and chest tightness and 48% of children who experienced wheezing reported a frequency of less than once a month (Table 6). Compared with the 2003 study, the percentage of children with frequent cough, at least once a month, showed a slight increase from 24.6% to 25.7%. However, for chest tightness and wheezing, the proportions decreased. Nonetheless, since these studies were cross-sectional in design with soft data (considering that these data were reported by respondents from recall), these increases or decreases with respect to the occurrence of respiratory symptoms must be interpreted with caution. Nonetheless, these data may be regarded as an indication of possible improvements in the general health of children in the study barangays.

Table 5. Exposure of Study Children to Cigarette Smoke, 2003 and 2008

Smoking history	Current Smoker N (%)	Former Smoker N (%)	Non-smoker N	Total N(%)
		2003		
Caregiver	29 (6.3)	11 (2.4)	418 (91.1)	458 (100)
Father	246 (53.6)	38 (8.3)	152 (33.1)	459 (100)
Mother	23 (5.0)	8 (1.7)	423 (92.2)	370 (100)
Other HH member	No data	No data	No data	No data
		2008		
Caregiver	20 (6.3)	5 (1.4)	345 (93.2)	370 (100)
Father	165 (44.6)	27 (7.3)	169 (45.7)	361 (97.6)
Mother	16(4.3)	4 (4.1)	343(92.7)	370 (100)
Other HH member	35(9.5)	0(0)	330 (89.2)	370 (100)

Table 6. Reported Respiratory Symptoms of Study Children and Frequency of Occurrence, 2008

Symptoms	Presence	Frequency of occurrence		
		<once a month	1-2x a month	>2x a month
	N (%)	N (%)	N (%)	N (%)
Frequent cough	95 (25.7)	49 (51.6)	25 (26.3)	21 (22.1)
Chest tightness	31 (8.4)	16 (51.6)	9 (29.0)	6 (19.4)
Wheeze	40 (10.8)	19 (47.5)	13 (32.5)	7 (17.5)

Table 7. Chest Diseases Diagnosed by a Medical Doctor in the Past Year, 2007

Disease	N (%)
Asthma	34 (9.0)
Bronchitis	18 (4.8)
Pneumonia	14 (3.8)

Out of the 370 children, only 25% (n=92) were reported to have had experienced certain chest illness in 2007. Among the reported chest illnesses, asthma was diagnosed in 34 children (9% of the 370 study children), bronchitis in 4.8%, and pneumonia in 3.8% of the study children (Table 7). There is a 50%-decrease in doctor-diagnosed asthma in 2007 in comparison to the 2003 study results, which was 20%. However, there was a slight increase in pneumonia and bronchitis combined, 7% in 2003 and 8.6% in 2007.

Results of the pulmonary function testing. The average demographic and pulmonary function characteristics of study children are shown in Table 8. For comparison purposes, Table 9 was prepared to show the average demographic and pulmonary function characteristics for 2003 as compared to the 2008 data. There were no significant differences on the average age and height of the 2008 study children compared with those studied in 2003. However, there was a difference of 8.5% in weight, which means that the children studied in 2008 were heavier, and a slightly lower average FEV1 (forced expiratory volume at 1 second) and FVC (Forced Vital Capacity) among the 2008 study children.

The FVC is a function of the integrity of the bigger airways (bronchi) while the FEV1 is a function of the smaller airways (alveoli). The lower values for FVC in this study may indicate probable obstruction or problems in the bigger airways. The same problem is true for FEV1, which applies to the smaller airways. Further comparison was made to determine the number and proportion of children with less than the predicted values (or "abnormal") for both the FEV1 and FVC. Table 10 presents the comparison of PFT results between the 2003 and 2008 study results by barangay. A comparison of the 2003 and 2008 studies showed that the number and proportion of study children with less than normal values FEV1 in 2008 increased about 10 times from

Table 8. Average Demographic and Pulmonary Function Characteristics of Study Children by Barangay, 2008

Barangay	N	Age (yrs.)	Weight (Kilos)	Height (cm)	FVC (liter)	FEV1 (liter)
Near Barangays						
Ibabang Polo	141	8.71	25.15	125.61	1.47	1.34
Ilayang Polo	60	8.56	25.59	126.1	1.44	1.36
Kanlurang Malicboy	23	8.83	24.29	123.71	1.52	1.38
Lipata	23	8.83	27.78	126.78	1.51	1.43
Tulay Buhangin	28	8.29	23.86	123.57	1.4	1.26
Far Barangays						
Alupaye	20	8.8	24.2	121.95	1.5	1.4
Bantigue	18	8.94	25.13	128.25	1.52	1.38
Daungan	17	8.37	26.63	126.11	1.41	1.3
Mapagong	19	8.84	22.42	123	1.4	1.28
Rizal	5	9.2	27.6	132.8	1.5	1.41
Silangang Malicboy	9	8.44	22.22	123	1.39	1.28
Sipa	7	8	21	118.86	1.35	1.23
Average	370	8.66	25	125.2	1.46	1.35

Table 9. Comparison of Average Demographic and Pulmonary Function Parameters in 2003 and 2008

Characteristics	2003	2008
Age (years)	8.69	8.66
Weight (Kilo)	23.1	25
Height (cm)	124.8	125.2
FVC (liter)	1.49	1.46
FEV1 (liter)	1.41	1.35

2003. There was no difference between the 2003 and 2008 studies in terms of "abnormal" FVC. There was no significant difference in the average FVC and FEV1 of children in "near" and "far" barangays. However, the number of children with FVC and FEV1 less than 80% of the predicted are higher in the "near" barangays when compared to the "far" barangays.

Predictors of respiratory symptoms and pulmonary function parameters. Table 11 summarizes the risk factors for the occurrence of respiratory symptoms and pulmonary function parameters. For respiratory symptoms, sex and weight of the child were significant correlates for frequent cough. Sex was a protective factor of frequent cough wherein males were less likely to have frequent cough than females. Those who weighed less than the average were 2.71 times more likely to have frequent cough. There were no significant correlates for chest tightness. For wheezing, the households with members who smoke were 3.7 times more likely to have children with wheezing.

In terms of pulmonary function parameters, the gender and height of the child significantly influenced the occurrence of FVC less than 80% of the predicted value. Male children were 2.69 more likely to have "abnormal" FVC than females and those children with less than the average height were 3.75 times more likely to have FEV1 less than the predicted than the taller children.

The significant risk factors for respiratory symptoms and pulmonary function parameters were generally demographic characteristics (sex, height, weight), reflecting the nutritional status of children. However, cigarette smoking and indoor PM_{10} levels, which emerged as significant risk factors for wheezing and predicted FEV1, respectively, reflect the environmental exposure of children inside their homes. All these risk factors can be easily managed by the household by improvements in the nutritional status of children and smoking cessation of household members. However, it should be noted that there might be other related factors also responsible but were not covered in this study.

Table 10. Comparison of PFT Results between 2008 and 2008 by Barangay

Barangay	2003			2008		
	No. of children monitored N	No. of children with FEV1 less than 80% of predicted N (%)	No. of children with FVC less than 80% of predicted N (%)	No. of children monitored N	No. of children with FEV1 less than 80% of predicted N (%)	No. of children with FVC less than 80% of predicted N (%)
Near Barangays						
Ibabang Polo	160	8 (4.8)	73 (45.6)	139	80 (57.6)	65 (46.8)
Ilayang Polo	69	4 (5.8)	28 (40.6)	61	39 (63.9)	25 (41.0)
Kanlurang Malicboy	0	0 (0.0)	0 (0.0)	24	13 (54.2)	10 (41.7)
Lipata	6	0 (0.0)	2 (33.3)	23	13 (56.5)	8 (34.8)
Tulay Buhangin	8	0 (0.0)	5 (62.5)	28	20 (71.4)	17 (60.7)
Far Barangays						
Alupaye	23	0 (0.0)	9 (39.1)	20	7 (35.0)	5 (25.0)
Bantigue	19	2 (10.0)	8 (42.1)	16	8 (50.0)	5 (31.3)
Daungan	27	5 (17.2)	13 (48.1)	19	13 (68.4)	11 (57.9)
Mapagong	45	3 (6.6)	15 (33.3)	19	11 (57.9)	11 (57.9)
Rizal	9	0 (0.0)	4 (44.4)	5	3 (60.0)	2 (40.0)
Silangang Malicboy	63	2 (3.0)	31 (49.2)	9	6 (66.7)	4 (44.4)
Sipa	21	1 (4.8)	10 (47.6)	7	5 (71.4)	3 (42.9)
Total	450	25 (5.6)	198 (44.0)	370	218 (58.9)	166 (44.9)

Table 11. Summary of Risk Factors for Respiratory Symptoms and Pulmonary Function Parameters, 2008

Symptom/PFT Parameter	Risk factor	Odds Ratio	95% confidence interval	p-value
Frequent cough	Gender-male	0.4	0.17 - 0.94	0.04
	Weight	2.71	1.12 - 6.54	0.03
Wheezing	Other HH member smoking	3.7	1.0 - 13.67	0.05
FVC/PFVC	Gender-male	2.69	1.13 -6.42	0.03
<80% predicted	Height	3.75	1.23 - 11.43	0.02
FEV1/PFEV1	Height	4.47	1.93 -10.39	<0.001
<80% predicted	Indoor PM10 levels	2.61	1.16 - 5.87	0.02

Conclusion

In summary, there is no difference on the 8-hr averages for PM_{10} between the "near" barangays and the "far" barangays. In comparison with the Philippine ambient standards, the adjusted 24-hour levels of indoor PM, SO_2 and NO_2 were all below the ambient standards. Likewise, there are no significant correlates for PM_{10} levels. It can be surmised that the indoor pollutant levels are almost the same between the potential contributing factors for indoor levels of particulate matter that significant variability cannot be established or the sample size is too limited.

The significant risk factors for respiratory symptoms and pulmonary function parameters are generally demographic characteristics (gender, height, weight) reflecting the nutritional status of study children. However, cigarette smoking and indoor PM_{10} levels which came out as significant risk factors for wheezing and the predicted FEV1, respectively, reflect the environmental exposure of children inside their homes.

Recommendations

In consideration of the findings of the study, the researchers recommend an annual environmental health monitoring program to continuously evaluate the environmental health problems, which are found to be related to the socio-economic and demographic characteristics of the communities surrounding the power plant. A capacity-building training should accompany the said monitoring program for the barangay health workers that aims to familiarize them with the processes, standards, and pertinent information regarding the program. The monitoring program should comprise two components, which include a) monitoring of facility-based consultations and b) monitoring of sentinel households, and should place specific emphasis on the environment-related illnesses that were identified in the 2008 study. The said diseases are (1) diarrhea, all types, (2) respiratory diseases (URTI, ALRI); and (3) skin diseases.

The monitoring of sentinel households should follow three steps: a) identification of sentinel households, b) active surveillance of sentinel households, and c) collation and analysis of collected data. In the first two steps, the barangay health workers are responsible for identifying the baseline data, training the respondents, and gathering and validating data. The third step requires the presence of the midwife in order to collect and analyze the data, with the assistance of the barangay health worker.

On the other hand, the monitoring of facility-based consultations involves recording the daily consultations in the Barangay Health Stations within the territory being monitored by the barangay health worker or those reported at the Barangay Health Centers managed by a trained midwife.

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