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Intensive Swine Production: Impact on Air Quality and Its Association with Community Residents' Respiratory Illnesses

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ABSTRACT

Inadequate waste disposal from an intensive piggery operation has resulted in community residents' disquiet about the poor air quality. This study (I) assessed the air quality in the community and (II) quantified the extent of symptoms related to respiratory ailments among residents. Measurements, done in the experiment and control areas, included; aerial emission levels of hydrogen sulphide and ammonia and respiratory symptoms of a sample of 172 residents. Results showed that: the highest levels of gas were measured directly outside the farm and gradually decreased as measurements were taken further from the farm; hydrogen sulphide levels were slightly higher than that of the ammonia levels at all test times in experiment area; no gases were detected in the control area; the values for both ammonia and hydrogen sulphide in the experiment samples were significantly lower than that of the established NIOSH Time Weighted Averages; residents in the experiment area reported a higher severity of most symptoms. Recommendations included I) education for the community to enable them to understand the risks faced II) more frequent visits from government health officials and III) persuasion to have the owners of the piggery modify its farm practices and to engage industry best practices.

Key words: Pig Farming; Ammonia; Hydrogen Sulphide; Malodours; Respiratory Illness; Trinidad

INTRODUCTION

The agriculture sector in Trinidad is important for the livelihood of a multitude of small farmers and their families. Government has also stated that the sector is crucial to meeting national food security goals. As such, farmers are encouraged and supported by the state to increase production and productivity on their farms. Some farmers have responded positively, and while most decisions made at farm level redound to the benefit of farmers, their families and the nation, the decisions of some create some undesirable situations. One such issue, inadequate waste disposal, now considered to be a poor farm practice has serious consequences for communities in the vicinity of farms. A farm, besides being involved in food production, has other benefits to the communities in which it exists; in addition to being a source of employment for local residents, it also brings people to the community and neighboring businesses to make agriculture-food purchases, which for rural communities are highly desirable.

In several regions worldwide, the presence of livestock in close proximity to residential areas raises questions about public health implications [1, 2]. As with all large manufacturing and production processes, farms produce varying amounts of effluents, either in the form of chemical waste, biological waste or physical waste. These effluents can have a detrimental effect on both the environment and neighboring communities if not properly managed. It may deter potential customers from visiting, cause irritation in the community, attract disease- carrying pests, frequent visits of health officials and negatively impact the health of residents.

In recent decades, the Trinidad population has grown, so too has the cumulative demand for food [3]. As a result, to meet food security goals, crops and livestock have been increasingly produced intensively on small parcels of land; lands that are usually in close proximity or even within residential communities.

While intensive crop farming has many documented negative effects on farmers, the community and the environment, it is intensive animal farming that is the more worrisome. Ilea [4] examined intensive livestock farming and its environmental and ethical concerns and noted that animals produce a large amount of biological waste as part of their normal bodily functions. The waste from pigs and cows in particular, contain a higher content of nitrogenous and carbon-based wastes such as ammonia, hydrogen sulphide, methane and particulate matter. Hobbs [5] indicated that waste, if not properly disposed of, can lead to environmental as well as human related health problems.

Currently, with greater emphasis being placed on environmental and human health and safety, concern has now begun to focus on the quality of life of people living close to areas of intensive livestock operation. Previous studies have focused on the effects on farmers, their workers and the environment. However, not much emphasis has been placed on looking at the impact on persons in close proximity to these operations in the tropics [6].

Residents, unlike workers, are more exposed on a day to day basis for a longer period of time. Simonton and Spears [7] reported that although the levels of the effluents to which residents are exposed maybe lower than those of farm workers; it is the long term exposure periods that make residents just as susceptible to disease. They further noted that exposure to harmful, breathable air over a long period of time in some cases can be just as catastrophic as short term exposures to ammonia (NH_3) and hydrogen sulphide (H_2S). Malodor and pollutant concentrations have been associated with self-reported stress and altered mood [8].

In air quality studies done by the Iowa State University and the University of Iowa Study Group [9], some of the ill effects of NH_3 were found to vary at different exposure concentrations. These illnesses include coughing, wheezing, nasal complaints, eye irritation, throat irritation and skin complaints, with high concentrations of NH_3 resulting in pulmonary illnesses and even death. Simonton and Spears [7], also noted that H_2S can cause headache, dizziness, nausea, vomiting, coughing, difficulty breathing, and irritation of eyes, nose, and throat. At high levels, H_2S can even lead to coma or even death.

Undesirable odors besides making an area undesirable, lowers aesthetics and property value. McGinley and McGinley [10] have also linked malodors to many undesirable health defects such as frequent headaches, nausea, difficulty concentrating, and other illnesses.

In Trinidad, there are three large intensive pig farms that produce approximately 90% of the pork produced locally. These farms are vertically integrated farrow to finish operations, each producing approximately 1000 to 1500 pigs per cycle; which is large for a small country like Trinidad. One such operation, the focus of this study, supplies 75% of the pork to Trinidad and Tobago's local market and also contributes to regional exports. It is located in the district of St Patrick, which is on the south western end of Trinidad and very close to the southern coastline. The farm occupies 32 acres of state lands and employs 149 individuals, most of whom are local residents. The wider geographic area comprises several contiguous communities surrounding the farm has an estimated population of 81,597 persons. This wider area constitutes the persons who may be potentially be affected by the operations of the piggery. The farm, the focus of the study, is appropriate for study as there are no other large farming operations anywhere in the wider geographic area and hence all emissions can be assumed to be from the farming activities.

There has been some disquiet in the normally peaceful rural community about the air quality and this has drawn some national attention. In an article published in one of Trinidad and Tobago's national newspaper, The Daily Express, on June 8th, 2013, it was noted that the pig farm was given notice by the Environment Management Authority (EMA) of Trinidad and Tobago to rectify its effluent problems or face closure. The farm was found to be in violation of the Water Pollution Rules and it was noted that since the inception of the farm nothing has been done to properly treat the biological waste from the animals. All waste is either directly released into waterways or released into manure ponds where bacteria feed on the organic waste releasing pungent odors into the environment. In spite of expressed concerns, the situation persists and warrants an investigation to help find a solution to improve the quality of life of residents.

The study (I) assessed the air quality in a community surrounding a commercial piggery operation (II) quantified the extent of respiratory symptoms of community residents and (III) recommended actions to improve the physical well- being of community residents.

MATERIALS AND METHODS

The study was conducted at two research areas; experiment and control areas. The experiment area was located in the village of Erin; situated within a 2000 meter radius from the intensive pig farming operation. The control area for the study was situated in the village of Palo Seco; approximately 5000 meters from the pig farming operation (Figs. 1 & 2).

This study was conducted in two phases: the first phase of the study investigated the aerial emission levels of hydrogen sulphide and ammonia in both the experiment and control communities using direct testing, while the second phase of the study investigated the extent of symptoms related to respiratory illness of residents in both communities using a survey methodology.

Air Testing

Air samples were collected over a seven day period in both the experiment and control areas in the months of April and June 2015. All samples were obtained at 6:00 AM and 6:00 PM on each test day. In the experiment area, the first air sample was taken directly outside the pig farm with further readings being taken at 500 meter interval increments from the farm. External factors such as temperature, humidity and

wind speed, prevailing winds were also recorded on test days. All samples were measured using the multiRAE portable multi gas meter, which has been used to measure a wide range of volatile organic compounds, combustible gases and radiation. It is reported to be the most advance portable chemical detector and allows for efficient and effective field testing with high precision of accuracy [11]. The meter was held at 2 meters from the ground which was representative of the breathing zone of most residents. The meter was turned on and the reading was allowed to stabilize before it was recorded. Measurements of ammonia and hydrogen sulphide were recorded. This procedure was repeated in the control area.

Fig. 1: Location of the two sample areas Erin and Palo Seco

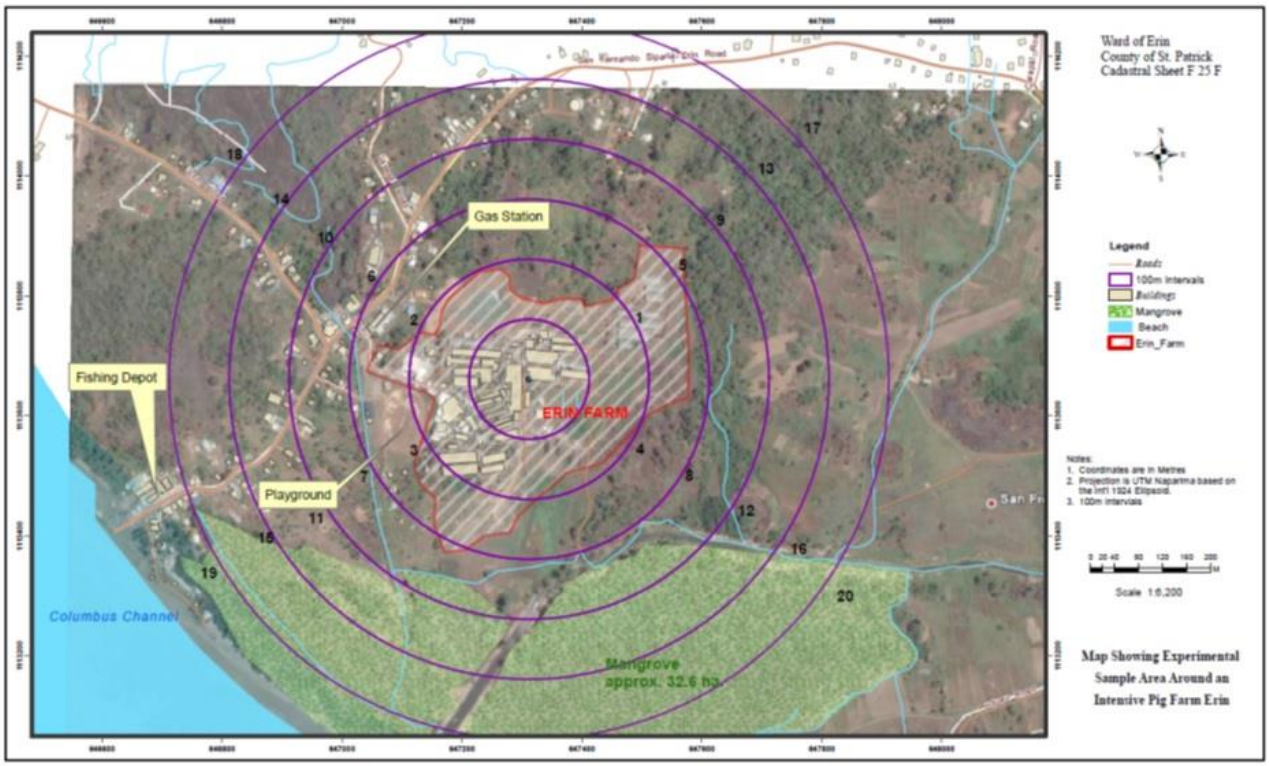

Fig.2: GIS map for the experiment area of Erin and the location of the different sampling sites

Survey of Residents

The catchment area of the wider area surrounding the farm has estimated the population of 81957 residents. A systematic judgmental sampling technique, as suggested by Punch [12], was used for the selection of participants from both the experiment and control areas. The required sample size of 172 residents was estimated using a 95% confidence interval, a Z value of 1.96 and a 5% margin of error. The sample population was then subdivided into two groups based on the study area location; therefore each group contained 86 possible respondents (86-experiment; 86-control). Personal and demographic data were collected as well as questions to assess residents' physical health. Physical health for each respondent was assessed over sixteen respiratory symptoms. Respondents were asked to indicate the frequency of symptoms such as dizziness, nausea, cough, etc. Respondents in both the experiment and control areas were assessed. Response categories were: Never (score =1); sometimes (score = 2, and often (score=3). All data obtained were kept strictly confidential, and anonymity was preserved. Respondents in the experiment group consisted of individuals aged 18 years and over living within a 2000 meter radius from the intensive pig farming operation in the village of Erin, Trinidad. The control group was also made up of individuals over the age of 18 years living in the same rural community, but who resided 5000 meters beyond the intensive pig farming operation in the adjoining village of Palo Seco. Questionnaires were pretested among 10 persons in the experiment area and the revised instrument was administered over a period of 4 weeks period by trained data collectors. Although there was general support for the survey among residents, one of the main reasons for not completing the questionnaires was that the farm employs members of their families and they did not want to participate in any activity that may cause the farm to close and result in job losses.

Statistical Analysis

Data were analysed using SPSS v21. Means and standard deviations were presented to describe the data set and the significance of the difference in the levels of ammonia and hydrogen sulphide levels between the control and experiment areas were assessed using t-test.

RESULTS

Description of Gas Levels

Gas Levels by Days of the Week

Fig. 3 shows the readings for gas levels of ammonia and hydrogen sulphide in the experiment area of Erin. In Fig. 3, it can be seen that for the month of April, the levels of both gases were highest on a Sunday. The lowest levels for ammonia were found to be on a Wednesday and the lowest level of hydrogen sulphide was found to be on a Tuesday. For the month of April, Palo Seco had no registered readings of either gas.

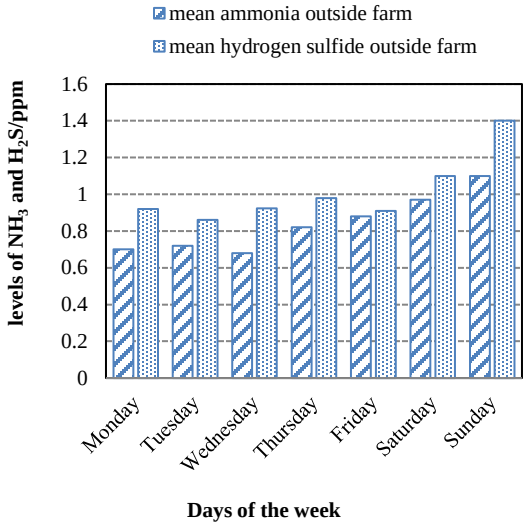

Fig. 3: Gas levels in April at Erin

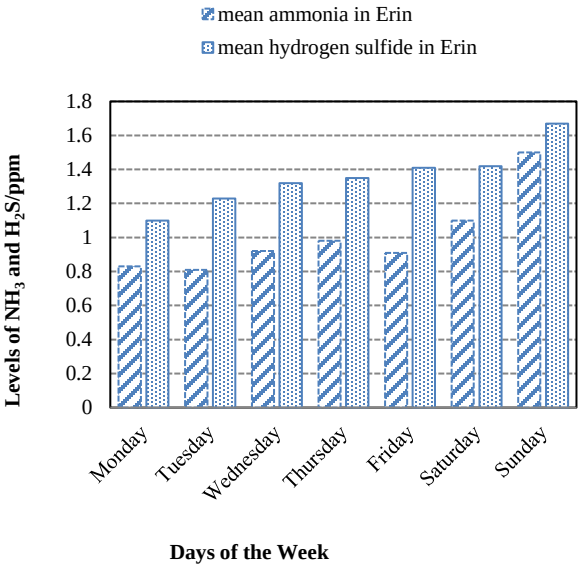

Fig. 4: Gas levels in June at Erin

Fig. 4 shows the gas levels for the month of June in Erin. It was observed that Sunday again appeared to have the highest levels of both gases measured. Tuesday had the lowest levels of ammonia and Monday had the lowest levels of hydrogen sulphide in Erin. Palo Seco showed no readings of either gas.

In comparing both charts, the readings appear to show a similar trend for both April and June, with June having slightly higher levels of both gases in Erin. No ammonia or hydrogen sulphide gas was found in Palo Seco on any of the test days.

Gases Levels by Distance from Farm

When comparing the average of both gases for both April and June in relation to the distance from the farm, Fig. 5 shows that the highest levels of gas were measured directly outside the farm and gradually decreased as measurements were taken further from the farm. In both months the hydrogen sulphide levels were slightly higher than that of the ammonia levels. No gases were detected in the control area of Palo Seco.

Gases Levels around the Farm

Figs. 6 and 7 show that the gases were detected in a uniform manner around the farm. In both months, highest gas levels were measured on the western side of the farm. The second highest gas level measured was to the south of the farm, followed by the north, with the least amount of gas measured being to the east of the farm.

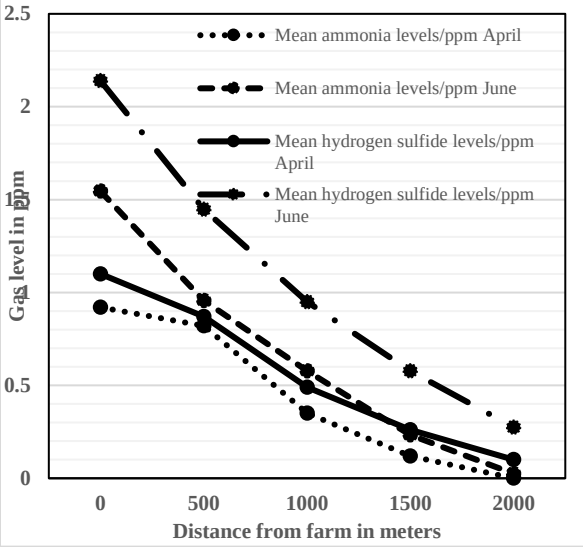

Fig. 5: Average of gases in relation to distance from the farm in Erin

Assessment of Ammonia and Hydrogen Sulphide Gas Levels

One sample t-tests were used to determine whether the experiment sample means differed significantly from the hypothesized National Institute for Occupational Safety and Health (NIOSH) value of 25ppm for ammonia and 10ppm for hydrogen sulphide. Statistical analysis indicated that the mean value for ammonia (0.92ppm) in the experiment sample was significantly ($p \leq 0.001$) lesser than that of the NIOSH time weighted average of 25 ppm. Similarly, sample mean (1.19 ppm) for hydrogen sulphide was significantly ($p \leq 0.001$) less vis-à-vis the hypothesized NIOSH value of 10ppm (Table 1).

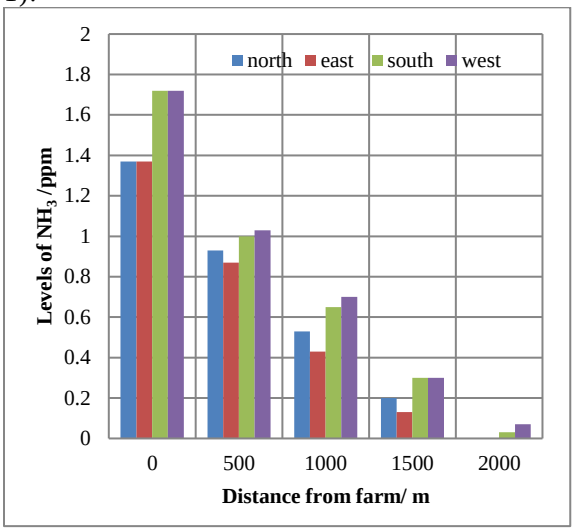

Fig. 6: Concentrations of NH_3 gas in different directions around the farm in Erin in month of April (wind: E 10 mph)

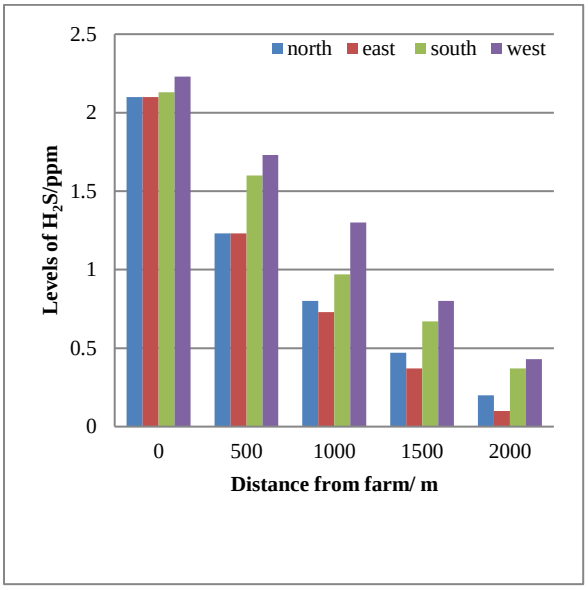

Fig. 7: Concentrations of H_2S gas in different directions around the farm in Erin in month of June (wind: ESE 7 mph)

Table 1: Results of one sample t-test for ammonia levels in Erin

Parameters	Mean	SD	t	df	P value
Ammonia levels in Erin	0.92	0.21	-424.65	13	0.000
Hydrogen sulphide levels in Erin	1.19	0.25	-132.02	13	0.000

Assessment of Symptoms Related to Respiratory Illnesses

Symptoms Exhibited

Once established that the gases and odor were present in the experiment area of Erin, respiratory symptoms exhibited by residents were investigated. Table 2 shows the percentage of reported cases of each symptom in both sampled communities of Erin and Palo Seco. From the table, it could be seen that the residents in the experiment area (Erin residents) reported a higher occurrence of all symptoms except for dizziness.

The farm residents were found to have a higher occurrence of headache, nausea, tiredness, exhaustion, eye, nose and throat problems, breathing problems, coughing, wheezing, sneezing, shortness of breath, blurred vision, sinus congestion, difficulty concentrating, pain and discomfort than the control population. This would suggest that the residents in the control area are in better physical health than the farm-area residents and this could be related to the odor in the area in which they live; since no other major odor generating activities were present in the wider area. In looking at individual symptoms, headache also appeared to be the most prevalent symptom reported in the experiment area whereas a cough appeared to be the most prevalent in the control population. The least prevalent symptom reported in the experiment area was blurred vision and the least prevalent for the control area was wheezing.

Table 3 shows the results of an independent t-test of mean symptom scores for the experiment and control area residents. Results exhibited that the overall mean score for respiratory illness-related symptoms in the experiment area (m= 1.75) was significantly (p= 0.00) more than that of the control area (m= 1.52). These findings suggested that the residents living in the close vicinity of swine farms have a higher incidence of respiratory ailments related symptoms that led to a lower overall physical health compared to those living away from the swine farming area.

Table 2: Percentages of reported respiratory symptoms in Erin and Palo Seco

Symptoms	% of reported cases in the experiment area (Erin)	% of reported cases in the control area (Palo Seco)
A headache	87.36	70.93
Nausea	59.23	43.02
Dizziness	33.33	39.47
Tiredness	71.26	60.47
Exhaustion	72.41	59.3
Eye, nose and throat	45.98	24.42
Breathing problems	45.98	45.35
A cough	78.16	75.58
Wheezing	48.28	15.12
Sneezing	79.31	62.79
Shortness of breath	55.17	26.74
Blurred vision	20.69	16.28
Sinus Congestion	54.02	48.84
Difficulty Concentrating	47.06	23.26
Pain	36.78	32.56
Discomfort	45.98	20.93

Table 3: Independent t-test comparing overall symptom scores between the two communities

Population	N	Mean Symptom score	SE	t-test for equality of means	
				t	p-value
Experiment (Erin)	86	1.75	0.06	3.50	0.00
Control (Palo Seco)	86	1.52	0.02		

DISCUSSION

From the results obtained, the hydrogen sulphide readings were higher than the ammonia readings throughout the test week. This could be due to the fact that hydrogen sulphide is caused by the anaerobic breakdown of waste after it is placed in the waste pond. The high level of ammonia could be due to nitrification and denitrification in the bed, which can prevent ammonia emission by producing N_2 from NH_4 instead of NH_3 [13]. The readings were also highest for both gases on Sunday; on Sundays, the smell became worse because there were no workers on the farm assigned to cleaning the animal stalls hence this could account for the increase in gas readings. Large, intensive operations are usually run as full-time enterprises to ensure sanitary conditions at all times. This appears to be an area to cut costs by the farm owners; however, the consequences are felt by the surrounding residents.

In looking at the distribution of the gases in different directions around the farm, it was seen that the highest

levels were to the west and south of the farm. This is due to both topography and wind direction. The farm is located in close proximity to the south coast of Trinidad which makes it exposed to sea breezes during the day. The sea breezes tend to blow inland, over the farm and in a westerly direction. The odors were then blowing directly over the residents' homes. This is the source of their discomfort and probably health related issues. Since prevailing winds cannot be manipulated, both in terms of intensity and direction, the responsibility is on the farm managers to mitigate the effects of the odor-carrying winds.

The study found that the further the distance from the farm, the less the concentration of gases became, hence it can be concluded with some certainty that the gases were emanating from the farm itself and that the farm was the source of the odors. To validate that the malodors were in fact from the farm in the experiment area, tests were done in a control community and no odors were detected nor odors reported by residents.

The measured ammonia gas was well below the permissible Time Weighted Average (TWA) limit of 25ppm. However, although the ammonia levels were below the TWA, it was way above the Agency for Toxic Substance and Disease Registry (ATSDR) recommended long term Maximum Residue Limit of 300ppb for community exposure. In a similar study, Shendrikar *et al.* [14] measured the ambient NH3 surrounding hog operations in North Carolina and found that the average ammonia levels for a five year period were between 0.002 to 0.015 ppm. This too was well below Acceptable Ambient Level (AAL) of 3.03ppm which was used as their reference value. NH3 reacts with particulate matter in the air and hence aerial concentration may be diminished. NH3 is water soluble and the air at Erin is very humid and this may account for the conversion of the NH3 into less reactive nitrate compounds.

Hydrogen Sulphide, with a measurement value of 1.19ppm, was much lower than the permissible level of 10ppm. However, the level is above the ATSDR recommended long term limits of 7 ppb. Van Aalst *et al.* [15] found that H_2S has a low odor threshold of less than 1ppm. So, although the levels of H_2S were not very high (1.19ppm) in Erin, it was still over the odor threshold which means that malodors would be detectable by the residents in the area.

The general conclusion is that although the ammonia and hydrogen sulphide levels are below NIOSH levels, they are still present in the atmosphere and would produce malodors. In addition, it is the low dose exposure over the long term that may have resulted in the respiratory and other symptoms experienced by residents, confirming the findings of Simonton and Spears [7]. This is an under-recognized fact; persons often perceive that it is the high exposure that is more dangerous. Both the farm owners and residents will have to be educated so that this situation can be minimized, if not completely stopped.

Odor disrupts life and can also cause changes, not only to a person's health but also mood [16]. In looking at the general health of both experiment and control populations, results showed that almost all the symptoms assessed had a higher occurrence in the community around the farm compared to those living away from the farm. In looking extensively at public health effects in confined animal feeding operations, Merchant *et al.* [17] found that even low doses ammonia and hydrogen sulphide can cause negative health problems. Their findings are supported by findings of this study that ammonia and hydrogen sulphide in the air are associated with a host respiratory irritation and other irritations. This situation in Erin, Trinidad is serious and needs urgent attention as Merchant *et al.* [17] reported there are other symptoms which are related to exposure to higher doses of the gases such as decreased lung function, pulmonary disease, edema, mental disorders and hindered olfactory disorders.

We conclude that the physical well-being of residents living around the farm is negatively affected by the low levels of both ammonia and hydrogen sulphide gases. The major implication is that if no actions are taken to drastically reduce these odor causing gases, then these residents will suffer even greater effects in the future.

Recommendations include education for the community to enable them to understand the risks that they face. This may encourage them to demand that the Environmental Management Authority (EMA) be more vigorous in testing and application of the rules and regulations governing air pollution in their area. Moreover, The Trinidad and Tobago Occupational Safety and Health Act (2004) entrusts local enterprises with the duty to protect the health, safety and welfare of employees and others who may be affected by company operations. The Act makes mention of health surveillance and medical examinations; however, these apply to employees and do not encompass surrounding communities. A revision of the Act is recommended.

The Regional Corporation, which administrates the wider area surrounding the study areas, can have their health officials visit the area more regularly and have the owners of the piggery modify its farm practices to engage industry best practices in all areas, but particularly for this urgent issue of waste management. Trinidad is a relatively small country and as more intensive farm operations emerge to meet food security goals, a model must be developed in which both farm and people can co-exist in a harmonious manner. A large, intensive farm operation can be an

asset for any community as it provides much needed jobs; however, corporate responsibility demands that the health of both the environment and people must be preserved. This study calls for more attention to be paid urgently to this issue.

ETHICAL ISSUES

There is no ethical issue.

CONFLICT OF INTEREST

Authors of the manuscript did not have a conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors equally help to write this manuscript.

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