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Hong Kong Air Pollution Effects on Student Absenteeism

## Introduction

Our health is directly influenced by the environment; just as what a child eats affects their physical, intellectual well being, so too does the air they breathe. Even for healthy people, adverse environmental conditions can cause respiratory irritation or breathing difficulties during exercise or outdoor activities. One's actual risk depends on your current health status, the pollutant type and concentration, and the length of your exposure to the polluted air. Given the many environmental respiratory diseases and the spectrum of possible predictive pathways this study converges our target population to individuals affected by asthma in Hong Kong. Specifically this investigation will focus on: 1) analysis ambient particles causing specific short term affects and 2) tracking of the cumulative effect of prolonged exposure on adolescent health and well-being in hopes of developing a predictive model. For my study I analyzed existing landmark studies on air pollutions effect on the lung health of children; then I built a predictive absenteeism model using this previous governmental health data and 200 adolescent survey responses that measured their ability to attend school when their health was compromised. Finally, I will interview 80 HKUST students to propagate potential short-term solutions for the identified issue.

Asthma is a ubiquitous respiratory disorder, which according to the statistical information from The Hong Kong Asthma Society, approximately 10% - 15% of children and 5% - 10% of adults experience recurrent symptoms of Asthma. Asthma is closely related to environmental factor as well as genetic factors, defined as a chronic inflammatory disease of airways that is characterized by increased responsiveness of the tracheobronchial tree to a multiplicity of stimuli. It is manifested physiologically by a widespread narrowing of the air passages and clinically by paroxysms of dyspnea, cough, and wheezing. Asthma is an episodic disease and, typically, most attacks are short-lived and clinically the patient recovers completely after an attack. There can be a phase in which the patient experiences some degree of daily airway obstruction. This phase can be mild, with or without superimposed severe episodes, or much more serious, with severe obstruction persisting for days or weeks; the latter condition is known as status asthmaticus. In abnormal circumstances, acute

episodes can cause death. The major reason leading to death is that a many patients have difficulty evaluating the severity of the disease's stage during an attack.

Every year in Hong Kong, more than 20 000 patients are admitted to hospitals with asthma exacerbations, the direct cost of which exceeds 650 million dollars. Sadly, about 80 patients die from asthma every year, of which the figure has been relatively stable since 1995. Despite the numerous medical and educational initiatives related to asthma treatment in Hong Kong amongst health care professionals, this statistic has not improved. We have to ask the question why so many asthmatics still develop frequent attacks and die, though modern effective and affordable treatments are readily available in developed societies such as in Hong Kong.

The increasing levels of certain environmental pollutants may be contributing to this confounding figure. Hong Kong is situated at the southeastern tip of China with a total area of 1102 km<sup>2</sup> and a population of 7.188 million as of 2015. The population density is 6300 people/km<sup>2</sup> and is one of the most densely populated cities in the world. Hong Kong's climate is sub-tropical, tending more towards the temperate for nearly half the year. Temperatures can drop below 10°C in winter and exceed 31°C in summer. About 90% of the rainfall occurs between March and September. Hong Kong is globally revered for its impressive rapid economic development; however, due to its limited land, some of this industrialization has come at the expense of the environment. The exacerbated air pollution may be a result of Hong Kong's stressed transportation demands. In Hong Kong, the roadside NO<sub>2</sub> and RSP level has persistently exceeded the permissible limits in the past 10 years which could be attributed to the incessant increase in road traffic and trapping of polluted air including vehicle exhausts by the city's tall buildings, the so-called canyon effect. Many residential areas are situated in close proximity to busy road traffic. As outdoor particles readily penetrate indoors, through AC vents, it is believed that PM measured at outdoor fixed sites would correlate closely with personal exposure. As this is closely related to a lot of environmental respiratory disease Asthma, it will be discussed in depth in this study.

More specifically, the crude hospitalization rate of adolescent for asthma in Hong Kong is similar to that in Australia, yet the prevalence of clinical asthma in Australia is about threefold that in Hong Kong. The adjusted case fatality rate of 5.6 per 100 000 in Hong Kong was comparable to that of Thailand and Poland,

while it was almost 4 times higher than rates in Canada and Finland in 2004. With increasing cases of asthma hospitalization and an inability to immediately nullify the levels of ambient air pollution, interim solutions including more accurate identification of trigger pollutants and resources for asthmatic children become critical.

According to a research study by Li Ka Shing Faculty of Medicine of the University of Hong Kong in 2006, an increase of 5.64% of daily asthma admission count was attributed by an increase in NO<sub>2</sub> level, and 3.76% by O<sub>3</sub>, 3.67% by PM<sub>10</sub> and 3.24% by PM<sub>2.5</sub>. This report was able to identify that asthma hospital admission counts in Hong Kong increased with ambient levels of NO<sub>2</sub>, O<sub>3</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub>, which are the most abundant air pollutants in the atmosphere. Furthermore, recent research by the Faculty of Medicine of the Chinese University of Hong Kong, significant associations were found between hospital admissions for asthma to 15 major hospitals in Hong Kong and the levels of NO<sub>2</sub>, O<sub>3</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub> from January 2000 to December 2005. For every 10 g/m<sup>3</sup> increase in NO<sub>2</sub>, O<sub>3</sub>, PM<sub>10</sub> and PM<sub>2.5</sub>, there were 2.8%, 3.4%, 1.9% and 2.1% increases in the rates of asthma hospitalizations respectively. The younger age group (0-14 years) tended to have a higher risk for each 10 g/m<sup>3</sup> increase in pollutants than those aged 15-65 years. Although adolescents make up 25 percent of Hong Kong's total population, they comprise 40 percent of all asthma cases. Ultimately, breathing fine particles, alone or in combination with other pollutants, can aggravate these individuals' asthma, causing greater use of medication and resulting in more medical treatment and hospital visits. (Wilhelm et al., 2013)

Particulate matter is the term used for a mixture of solid particles and liquid droplets found in the air. Coarse particles (larger than 2.5 micrometers) come from a variety of sources including windblown dust and grinding operations. Fine particles (less than 2.5 micrometers) often come from fuel combustion, power plants, and diesel buses and trucks. They are of critical health concern because they easily reach the deepest recesses of the lungs. (Wong et al., 2001) Experiments both in vivo and in vitro reveal that fine or ultra-fine particulate matter can result in pulmonary inflammation, airway hyper-reactivity, alveolar macrophage impairment, epithelial cell damage, and epithelial permeability increase (Okeson et al., 2003, Renwick et al., 2001, Kwon et al., 2002 and Korenyi-Both et al., 1992). There has been a battery of scientific studies that have linked particulate matter, especially fine particles (alone or in combination with other air pollutants),



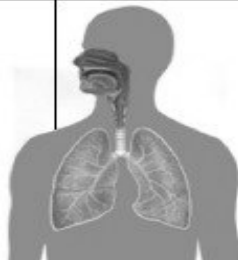
with a series of significant health problems, including premature death, respiratory related hospital admissions and emergency room visits, aggravated asthma, acute respiratory symptoms (i.e. aggravated coughing and difficult or painful breathing), chronic bronchitis, decreased lung function that can be experienced as shortness of breath, and work and school absences. (Environmental Protection Agency, 2015)

An in-depth landmark review of the association between air pollution and lung function growth in Southern California Adolescents found that the estimated growth rate for adolescents in the most polluted of the communities as compared with the least polluted was predicted to result in a cumulative reduction of 3.4% in FEV<sub>1</sub> and 5.0% in MMEF over the 4-yr study period. (Gauderman et al., 1999) This is a result of adolescents breathing 50 percent more air per pound of body weight than adults; because adolescents' respiratory systems are still developing, they are more susceptible to environmental threats than healthy adults.

There are several biological reasons why young adolescents may be more susceptible to air pollution's effects. Adolescent's lungs, immune system, and brain are immature at birth and continue to rapidly develop until approximately age 6, and the cell layer lining the inside of the respiratory tract is particularly permeable during this age period. The process of early growth and development is important to the health of the adolescent in general, and therefore may also be a critical time when air pollution exposures can have lasting effects on future health. Additionally, adolescents tend to spend more time outdoors doing strenuous activities, such as playing sports, so they are breathing more outdoor air compared to adults, who spend on average about 90% of their time indoors. Exposure to fine particles is associated with increased frequency of adolescence illnesses, which are of concern both in the short run, and for the future development of healthy lungs in the affected adolescents. (Hong et al., 2006) Fine particles are also associated with increased respiratory symptoms and reduced lung function in adolescents, including symptoms such as aggravated coughing and difficulty or pain in breathing. These can result in school absences and limitations of normal adolescence activities.

Air pollution's general effect on public health is commonplace; however, this study will focus on specifically which ambient particles affect what part of the body as well whether or not the effect is an acute 24 hour reaction or if it is the culmination of prolonged exposure to combined pollutants over the span of 1-5 days.

Figure 1. Lung Development Windows

Stage: Age:	Newborn 0-2 mos	Infant/Toddler 2 mos-2 yrs	Young Child 2-6 yrs	School-Age Child 6-12 yrs	Adolescent 12-18 yrs
Lung development:					
	Alveolar development				
Air pollution risks:	High respiratory rate				
			Increasing lung volume		
	Respiratory death				
			Chronic cough and bronchitis		
			Reduced lung function		
			Wheezing and asthma attacks		
		Respiratory symptoms and illnesses*		Respiratory-related school absences	

\*Air pollution exposure has also been more recently linked to respiratory symptoms and illnesses in early life including cough, bronchitis, wheeze and ear infections

Retrieved from: Wilhelm, Michelle, and Ritz Beate. "Air Pollution Impacts on Infants and Adolescents," UCLA Institute of the Environment and Sustainability." N.p., 2013. Web. 01 July 2015.

Figure 2. Hong Kong School Structure

Age on birthday in school year	Year	Curriculum Stages			Schools		
2	N/A	Pre-school Education			N/A		Kindergarten
3					Nursery School		
4							
5							
6	Primary 1	Primary Education			Primary School or Junior School		
7	Primary 2						
8	Primary 3						
9	Primary 4						
10	Primary 5						
11	Primary 6						
12	Secondary 1	Secondary Education	Secondary Education	Secondary Education	Secondary School, Sixth Form College, or High School	ESF Secondary School	Middle School
13	Secondary 2						
14	Secondary 3						
15	Secondary 4	Diploma of Secondary Education	International Baccalaureate	GCSE / iGCSE			
16	Secondary 5			A levels / International Baccalaureate			
17	Secondary 6 {HKDSE} / Lower Sixth						
18	Local undergraduate	N/A	N/A	N/A	N/A	N/A	

Retrieved from: Structure.15.nment and Susi>Wikipedia</i>. Wikimedia Foundation, 16 May 2015. Web. 01 July 2015.

## Differential diagnosis

Age	Common	Uncommon	Rare
Less than 6 months	Bronchiolitis Gastro-esophageal reflux	Aspiration pneumonia Bronchopulmonary dysplasia Congestive heart failure Cystic fibrosis	Asthma Foreign body aspiration
6 months - 2 years	Bronchiolitis Foreign body aspiration	Aspiration pneumonia Asthma Bronchopulmonary dysplasia Cystic fibrosis Gastro-esophageal reflux	Congestive heart failure
2 - 5 years	Asthma Foreign body aspiration	Cystic fibrosis Gastro-esophageal reflux Viral pneumonia	Aspiration pneumonia Bronchiolitis Congestive heart failure Gastro-esophageal reflux

Most children who have asthma develop their first symptoms around **2 years** of age. However, asthma in young children (aged 0 to **5 years**) can be hard to diagnose. However it is often hard to classify it as asthma in Emergency because the symptoms of asthma also occur with other conditions before the age of 2.

Although respiratory complications instigated by air pollution have become a global epidemic, Hong Kong has the ability to serve as a telling flashpoint for this issue as it faces a particularly intensified and geographically contained situation. The prevalence rates of current wheeze, speech limiting wheeze, rhinoconjunctivitis and flexural dermatitis are significantly more common in Hong Kong than in Beijing or Guangzhou despite Mainland China displaying the most obvious “smog” trademark of air pollution. In 2001 Dr. Christopher K. W. Lai’s research group found that the atopy rate to be higher in Hong Kong (41.2%) than in Beijing (23.9%) or Guangzhou (30.8%). Atopy was strongly correlated with current wheeze (OR 7.74; 95% CI = 5.70–10.51). Early adolescence is also a critical period for the continued development and maturation of several biological systems such as the brain, lung, and immune system. Air toxins can impair lung function and neurodevelopment, or exacerbate existing conditions, such as asthma (Figure 2). PM<sub>2.5</sub> can pass into the deepest regions of the lungs and the alveoli (or alveolar sacs), which are still developing in adolescents under the age of 7. (Wilhelm et al., 2013)

In addition to the short-term consequences of obstructed lung development, dysfunctional pulmonary homeostasis and repair, including diseases such as pulmonary fibrosis (PF), chronic obstructive pulmonary disease (COPD), and tumorigenesis have been increasing over the past decade, a fact that heavily implicates environmental influences. Several investigations have suggested that in response to increased transforming growth factor - beta (TGF $\beta$ ) signaling, the alveolar type II (ATII) epithelial cell undergoes phenotypic changes that may contribute to the complex pathobiology of PF. Previous studies demonstrate that increased tissue stiffness associated with PF is a potent extracellular matrix (ECM) signal for epithelial cell activation of TGF $\beta$ . However, recent work reported here explores the relationship between tissue stiffness and exposure to environmental stimuli in the activation of TGF $\beta$ . They hypothesized that exposure of ATII cells to fine particulate matter (PM<sub>2.5</sub>) will result in enhanced cell contractility, TGF $\beta$  activation, and subsequent changes to ATII cell phenotype. (Barker et al., 2014) These abnormal developmental changes in adolescent lungs (age 0-12) will cause serious long-term respiratory issues with exacerbated asthma in secondary school years (age 12-18) perhaps being less serious in comparison. Ultimately, as an adolescent gets bigger, so do the airways in his lungs. Inflammation of airways, an asthma hallmark, could then go on unnoticed. Thus, it is critical that the



measurement period includes all the windows of development for adolescent lungs (0-18 years) where pollutant particles could become lodged anywhere in these critical windows and later display asthmatic symptoms; whereas, past the age of 18 particle lodgment in lungs may not display noticeable and measureable health effects due to the larger space of fully developed alveoli sacs and small airways.

Pivotal to this study is the impact of these asthmatic symptoms on school attendance one of the most important daily activities in the life of an adolescent. Many factors can contribute to student absenteeism. Family health or socio-economic status, poor school climate, drug and alcohol use, transportation problems, and differing community attitudes towards education are among the conditions that are often associated with an adolescent's frequent absence from school. However, chronic absence (regardless of reason) is increasingly identified as an important "early warning sign" that a student is at risk for school failure and early dropout. Chronic absenteeism is usually defined as missing ten percent or more of school days—asthma is the leading manifestation of this problem. (McClusky et al., 2004) Excessive school absence disrupts learning and is a strong predictor of premature school dropout. School-aged adolescents with asthma are absent more often compared to their healthy peers without asthma; yet, the causes of their respiratory adjutancy are inadequately documented. On average those with asthma (9.7% of students) are absent approximately 1.5 more days per month or per year compared to those without asthma. In one study, out of 1537 tracked absences that resulted from illness, 478 (31%) were due specifically to asthma-related symptoms. Adolescents with asthma are absent from school more often compared to their healthy peers and this appears to be driven by the underlying severity of symptoms. (Moonie et al., 2006) Furthermore, absenteeism negatively impacts standardized test level achievement. Although more research is warranted on the effects of persistent asthma on academic achievement, students with persistent asthma show a trend of performing worse on MAP standardized test scores and have more absence days compared with other students.

There is extensive literature that states the significant effect of air pollution's exacerbation of allergic reactions and harmful side-effects on outdoor physical activity; yet, the Hong Kong government has put forth minimal effort into more detailed analytics and policies to address the complexity of the situation, such as how it affects classroom engagement. It is in this same vein air pollution's secondary effects such as sunlight

reduction, immune system compromise, and its ability to change cytokine expression (which controls inflammatory response in the body) and subsequent hypothalamus size due to inflammation within the brain should be investigated deeper. Specifically, it may be beneficial to study air pollution's relationship to other widespread public health issues that face Hong Kong's adolescents, such as the mounting suicide rates, as it may present unforeseen correlations to stimulate new government policies.

## **Methods**

There are numerous data barriers when conducting public health related research in a region foreign to the researchers. Thus, it is critical that chosen methodology for a study maneuvers these obstacles in a way that the researcher is able to obtain the data to test their original hypothesis. Hong Kong's research culture provides a unique environment, such that certain public health studies that are commonplace in other places, specifically ones that exact secondary implications of health on the overall well-being of individuals. In the case of Hong Kong health data and data that involves children requires an extremely lengthy process for access where the research is at arms-length from governmental or professional health-provider affiliation. Consequently, ingenuity in methodology becomes critical towards reaching the goal of constructing progressive research that adds to, rather than reiterates, previous discoveries of Hong Kong's major health professionals, the primary disseminators of information impacting government knowledge and subsequent action.

To the best of our knowledge, the effect of air pollution on student absenteeism has never been studied in Hong Kong. The combination of the decentralization of student attendance records and the sensitivity with which each school views this student information, has made it extremely challenging to curate enough data for a comprehensive study to soundly evaluate the correlation of truancy and AQI. However, at the root of questioning how air quality affects the school attendance of students, is the assumption that the health of these children is being affected by the air they are breathing. Ultimately the consequence of this relationship likely reduces their ability to fully engage in the classroom.

To explore this connection I constructed a questionnaire in English and Chinese to give to a representative percentage of Hong Kong students that had missed one day of school where they were admitted to a hospital. This method for gauging absenteeism may actually be more effective than nondescript attendance records because it only accounts for individuals who are absent due to health reasons rather than a myriad of reasons that are hard to tease out if trying to quantify specific correlations when just observing overall attendance. In effect, this methodology gives voice to these absences. Additionally, this collection method has the ability to give us a general framework for beginning to approximate current Hong Kong wide absences for children under the age of 18. Conversely, looking at attendance on an individual basis as has been done in North American and European studies of this type, would limit a Hong Kong specific study to one school for one year as these individually kept records are not longitudinally archived. In essence, there is a two-factor amplification of data available in order to comprehensively analyze absenteeism anywhere in Hong Kong—rather than a specific school, region, and consequent socioeconomic demographic. This also nullifies the effect that differing socioeconomic statuses have on asthma frequency, severity, and treatment quality.

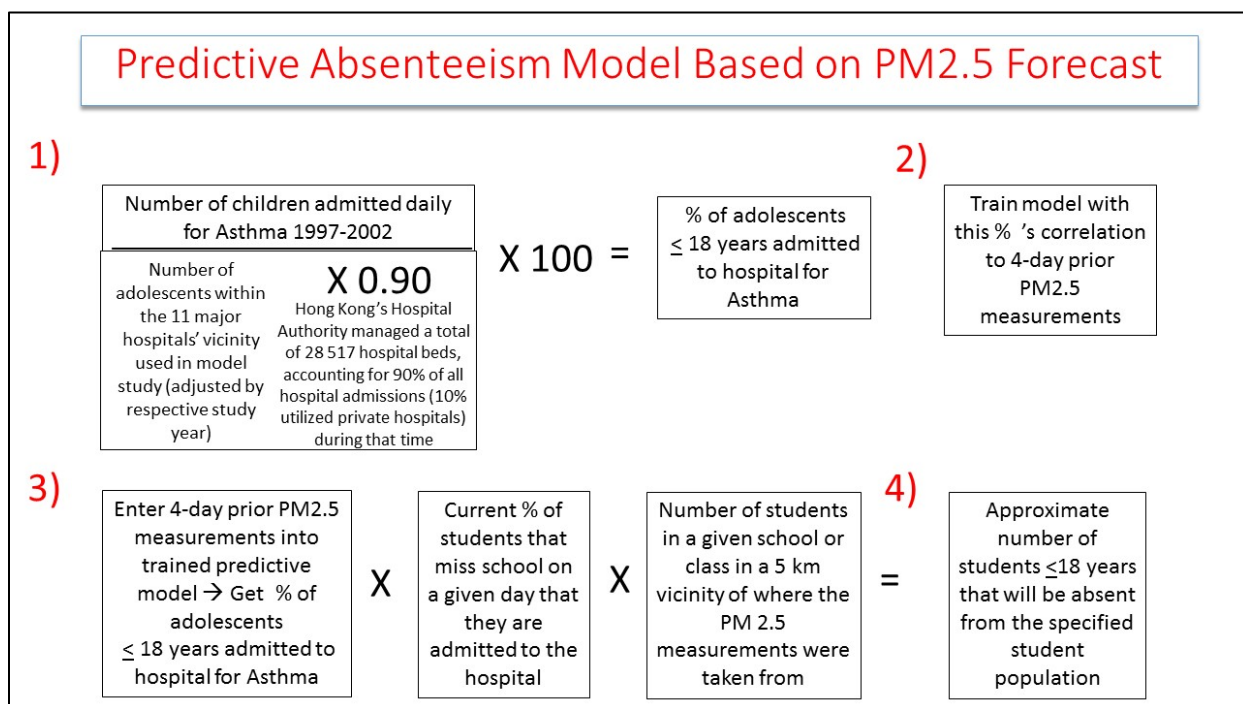
Since 1995, all inpatient data from the Hospital Authority, Hong Kong's public hospital administration, including demographic characteristics, dates of admission and discharge, diagnoses and procedures on discharge using the International Classification of Diseases, 9th, Revision, Clinical Modification (ICD-9-CM), have been stored in a central-computerized database. Although health data is not easily accessible from the Hospital Authority, their centralized electronic system have allowed for them to collect longstanding data and do comprehensive statistical analysis of this data, which they then publish the overall findings of. In 2006, the Health Authority curated past data on hospital admissions for asthma, influenza and total hospital admissions in children up to 18 years of age at all Hospital Authority hospitals during 1997–2002 were obtained; the time frame was limited due to the outbreak of SARS in 2003 where influenza admissions' ability to nullify seasonal-effect on Asthma admission was lost. Data on daily mean concentrations of particles with aerodynamic diameter of 10  $\mu\text{m}$  (i. e. PM<sub>10</sub>) and of 2.5  $\mu\text{m}$  (i. e. PM<sub>2.5</sub>), nitrogen dioxide (NO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), and ozone (O<sub>3</sub>) and data on meteorological variables were associated with asthma hospital admissions. The high accuracy of this data can be determined by evaluating the soundness of this critical previous study's methods in

combination with the statistical verification of their results. The researcher's used Poisson's regression with generalized additive models for correction of yearly trend, temperature, humidity, day-of-week effect, holiday, influenza admissions and total hospital admission. The possibility of a lag effect of each pollutant and the interaction of different pollutants were also examined. Their results showed that the association between asthma admission with change of NO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub> and O<sub>3</sub> levels remained significant after adjustment for multi-pollutants effect and confounding variables, with increase in asthma admission rate of 5.64% (3.21–8.14) at lag 3 for NO<sub>2</sub>, 3.67% (1.52–5.86) at lag 4 for PM<sub>10</sub>, 3.24% (0.93–5.60) at lag 4 for PM<sub>2.5</sub> and 2.63% (0.64–4.67) at lag 2 for O<sub>3</sub>. Effect of SO<sub>2</sub> was lost after adjustment.

Extant research indicates that ambient levels of PM<sub>10</sub>, PM<sub>2.5</sub>, and NO<sub>2</sub> are most significantly associated with childhood asthma hospital admission in Hong Kong. To analyze which air pollutant and which lag time combination would show the most effectual relationship on youth's health and ultimately absenteeism. In general, the concentration of gaseous pollutants and RSP are determined continuously by automatic analyzers. Manually operated high volume samplers using the gravimetric methods are also used regularly to measure the RSP. Meteorological data including mean temperature, humidity and atmospheric pressure were obtained from the Hong Kong observatory. I personally curated the five years of daily hospital admission data for PM<sub>10</sub>, No<sub>2</sub>, and PM<sub>2.5</sub> from a comprehensive pioneering study conducted by the Hong Kong Health Authority from 1997-2002. However instead of using their eleven stations, which they chose to weight equally throughout all of Hong Kong, I chose to weigh the effect of exposure on the largest daily population that is constituted by the three most industrial regions of Hong Kong that have the highest rates of foot traffic: Central, Causeway Bay, and Mong Kok. I hypothesized that by focusing on a group exposed to the worst roadside pollution would more clearly demonstrate the effectual patterns and relationships on time-series graphs. From this I was able to determine which pollutant to base my predictive model for Asthma hospital admissions and absenteeism on.

In order to extract the Hospital Authority's inaccessible yet extensive hospital data from this study, I used Engauge, a plot digitizing software. This computer program engages two algorithms for automatic digitizing of two-dimensional plots or graphs. The program renders information useful as it becomes malleable through the

data's conversion into standard x-y values (table format) of the original data for new analysis. Once converted, the user can make use of the information for function approximation, constants calculation, model fitting, statistical and mathematical analysis, integration and differentiation, prediction, parametrization. I was able to use this raw hospital data information present a different personalized plot with my new choice of stations and to train my predictive model. As the graphs published by the Hospital Authority presented over 2000 data points there were some gaps where the program was not able to exact a hospital admission number due to limited pixel precision. I then used R-Project software to interpolate a smooth spline function. When data is noisy, one fits it using a smoothing spline. The smoothing spline  $s$  is constructed for the specified *smoothing parameter*  $p$  and the specified weights  $w_i$ . There was extremely high accuracy in this method as the Hospital Authority actually used a smooth spline to create their graphs—so I was essentially translating it back into their original formatting. This exacting interpolation procedure allowed for me to have consecutive exact numbers to reanalyze for new relationships and use to train my model. Through this I obtained raw data on daily hospital admissions for asthma (ICD-9-CM code 493) as primary diagnosis upon discharge, influenza (ICD-9-CM code 487) as primary diagnosis upon discharge for control of viral respiratory seasonal epidemics and the total hospital admissions in patients  $\leq 18$  years of age from all hospital authority hospitals from January 1997 to December 2002.



As delineated in Figure 3, I then created a predictive model using historical youth asthma hospital admissions and PM2.5 measurements, in conjunction with current projected proportion of students that do not attend school if they are admitted to the hospital for their respiratory issues. Predictive modeling is a process used in predictive analytics to create a statistical model of future behavior. Predictive analytics is the area of data mining concerned with forecasting probabilities and trends. In predictive modeling, data is collected for the relevant predictors, a statistical model is formulated, predictions are made and the model is validated (or revised) as additional data becomes available. The model may employ a simple linear equation or a complex neural network, mapped out by sophisticated software. The goal of a supervised learning algorithm is to obtain a classifier by learning from training examples. A classifier is something that can be used to make predictions on test examples. This type of learning is called “supervised” because of the metaphor that a teacher (i.e. a supervisor) has provided the true label of each training example. (Elkan, 2013)

This model, shown in Figure 3, can soundly be applied to absenteeism because 87 % of adolescents under the age of 18 attend school in Hong Kong. Additionally, the age where each child in Hong Kong are required to start attending schools is also the age where asthmatic symptoms become differentiable and diagnosable. The absenteeism projected percentile was obtained by a questionnaire take from a 200 person sample size of adolescents and parents of adolescents from outside of the three largest public hospitals in Hong Kong. There were at least 10 individuals from each age group to give evenly distributed representation of target population’s school attendance that was being assessed. Furthermore, I tested the accuracy of this predictive model using HKUST as a case study. I will use the PM2.5 concentrations from an on-campus station to predict monthly Asthma-related hospital admissions and compare the sum of those numbers with the already recorded monthly Asthma admissions number from the on-campus hospital.

As public health is highly affected by local culture, it is hard to fully exact the causes of focus issue if the researcher is foreign to the environment. In light of this, anecdotal evidence from the target population, as well as from populations that are effecting the target group, become integral in attempting to explain extracted data. The previous study conducted by the Hospital Authority showed a strong effect of air pollution on adolescent lung health, I wanted the final stage of my study to use this knowledge to seek tangible short and long-term

change. Thus, to look for possible areas of improvement to help reduce the number of youth being affected by the growing issue of air pollution. Firstly, I evaluated the current air pollution research landscape in Hong Kong to see what information was being supplied to the government to impact their policy. Perhaps the current perspective on air pollution needs to be reframed. Within the current framework the generally accepted theme that air pollution is “bad” may in fact breed a level of complacency.. Without specificity of the gravity of certain pollutant levels and direct outcomes, that research studies have the ability to succinctly present, it is unlikely that the government will feel a deeper sense of urgency to come up with mitigating short-term solutions. Novel research on air pollution in Hong Kong can tangibly demonstrate how Hong Kong’s daily living may be impacted; ultimately, this can help deconstruct current political apathy towards the subject and propagate serious conversations for immediate change to public health policy. For example more exploratory mix method research studies using both qualitative and quantitative data (e.g., student, teacher and parent surveys conducted in tandem with specific data analytics on absenteeism, measures of student engagement, academic test scores and concurrent particulate). Research partnership with schools and parents could give more of a face and voice to the possible problems that exist and proactive solutions.

Finally, in order to assess the knowledge and action gap at the level of the government/ health authorities, educators, and students, I conducted a widespread survey and two interviews, one with Dr. Alexis Lau who is a public health and environmental professor at HKUST and the other with Ling Yi who is the head administrator of HKUST’s on-campus hospital. Qualitatively assess the causes of the knowledge and action gap from the perspective of the individual affected, that allow for the model to produce excessively high incident numbers and money spent on asthma treatment when compared to places with equivalent Asthma diagnosis rates but different treatment, resources, and air pollution restrictions.

## Results

Table 1. Summary of environmental variables and daily asthma hospital admission data in Hong Kong, 1997–2002

Pollutant variable	Mean $\pm$ SD	Percentiles			IQR
		25th	50th	75th	
Environmental variables					
Temperature (°C)	23.7 $\pm$ 4.8	20.0	24.8	27.8	7.8
Humidity (%)	78.1 $\pm$ 10.0	74	79	85	11
Rainfall mm	7.4 $\pm$ 23.5	0	0	2.3	2.3
Pollutant variable ( $\mu\text{g}/\text{m}^3$ )					
PM <sub>10</sub> (24 h)	56.1 $\pm$ 24.2	37.3	51.1	70.7	33.4
PM <sub>2.5</sub> (24 h)	45.3 $\pm$ 16.2	33.4	43.0	54.0	20.6
SO <sub>2</sub> (24 h)	17.7 $\pm$ 10.7	10.6	15.2	21.7	11.1
NO <sub>2</sub> (24 h)	64.7 $\pm$ 20.9	49.7	63.5	76.8	27.1
O <sub>3</sub> (8 h)	28.6 $\pm$ 16.0	15.9	25.4	38.9	23
Hospital daily admission (number)	401 $\pm$ 90.7	332	404	468	136
Asthma daily hospital admission (number)	12.1 $\pm$ 5.4	8	11	15	7
Influenza daily hospital admission (number)	2.7 $\pm$ 4.3	0	1	3	3

Observation period was 2191 days, total, hospital admission was 879 384, asthma admission was 26 663 and influenza admission was 5821. PM<sub>10</sub>, aerodynamic diameter < 10  $\mu\text{m}$ ; PM<sub>2.5</sub>, aerodynamic diameter < 2.5  $\mu\text{m}$ ; SO<sub>2</sub>, sulphur dioxide; NO<sub>2</sub>, nitrogen dioxide; O<sub>3</sub>, ozone.

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Table 1 hospital admissions, and for meteorological and pollution variables equally weighted throughout all of Hong Kong's AQI measuring stations. There were 879 384 total hospital admissions, 26 663 asthma admissions and 5821 influenza admissions for children  $\leq 18$  years of age recorded with the respective daily average admission of 401, 12.1 and 2.7 over the 6-year study period. Standardized annual total hospital admission, admission for asthma and influenza were about 999, 31 and 7 per 10 000 children  $\leq 18$  years, respectively, based on population figures. There was a decreasing trend in annual total hospital admissions until year 2002, while annual asthma admission rate remained fairly constant over these 6 years, resulting in an increasing contribution of asthma admissions to total hospital admission ( $P < 0.001$ ).



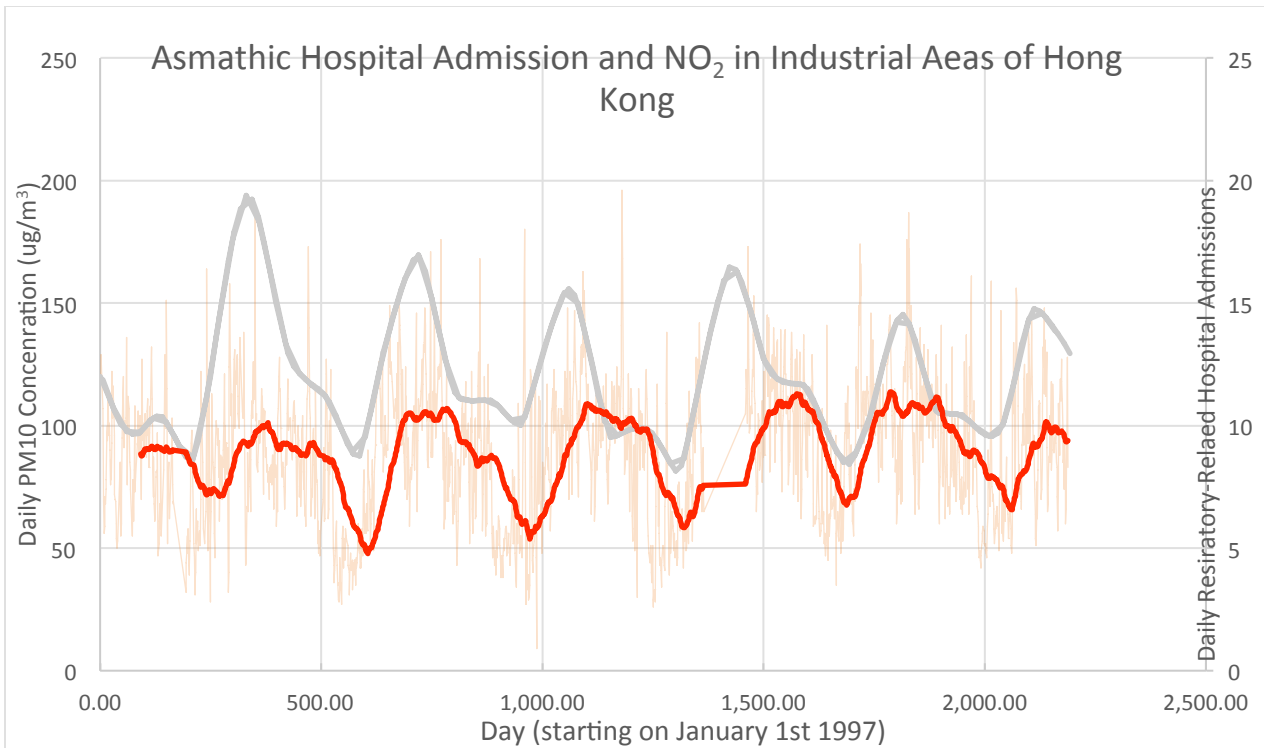


Figure 1: Time-series analysis of particular ambient pollutant in Hong Kong areas with highest daily population density in relation to daily asthmatic admission patterns

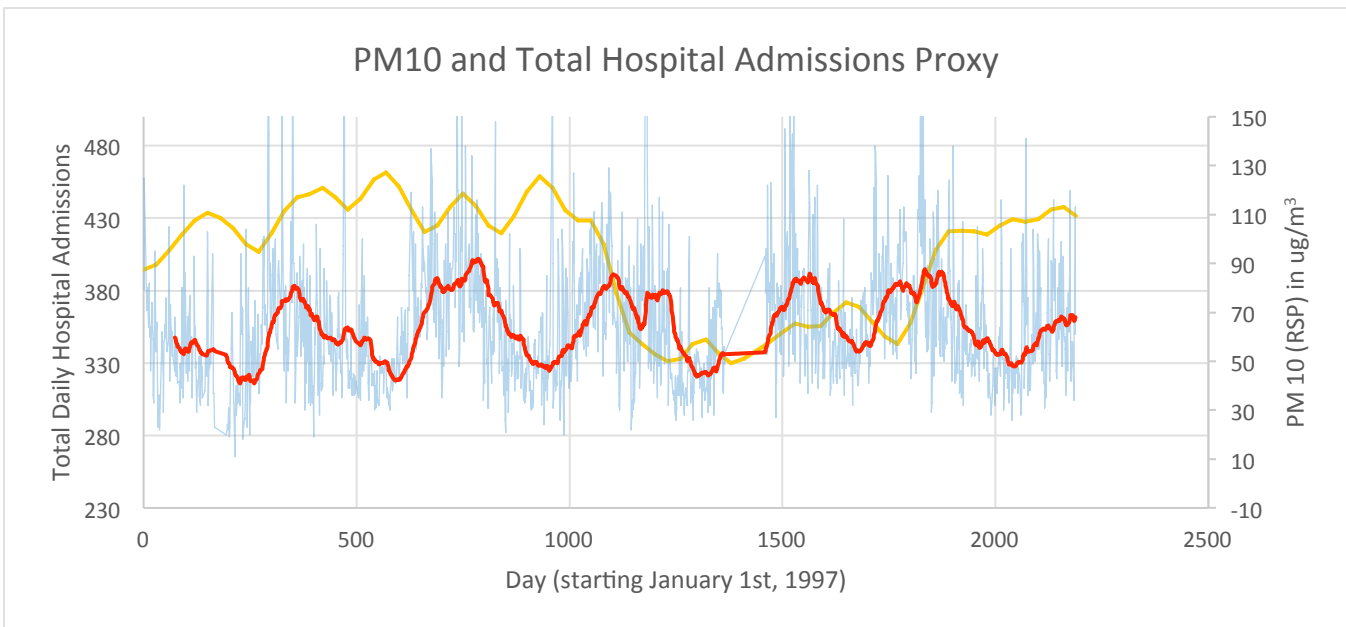


Figure 2: Time-series analysis of particular ambient pollutant displaying a null effect on daily hospital admission patterns as signified by the nonlinear correlation between pollutant levels and general hospital admission numbers.

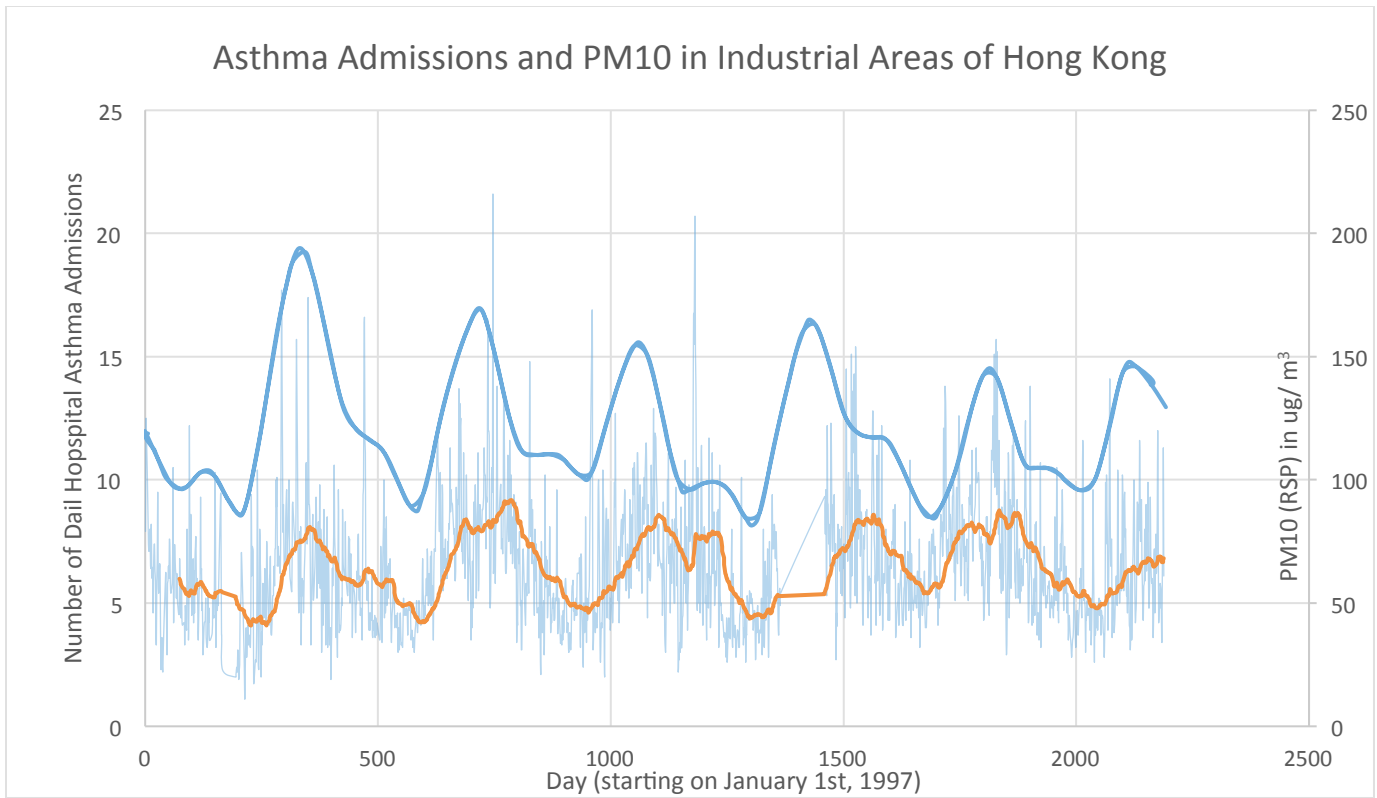


Figure 3: Time-series analysis of particular ambient pollutant in Hong Kong areas with highest daily population density in relation to daily asthmatic admission patterns

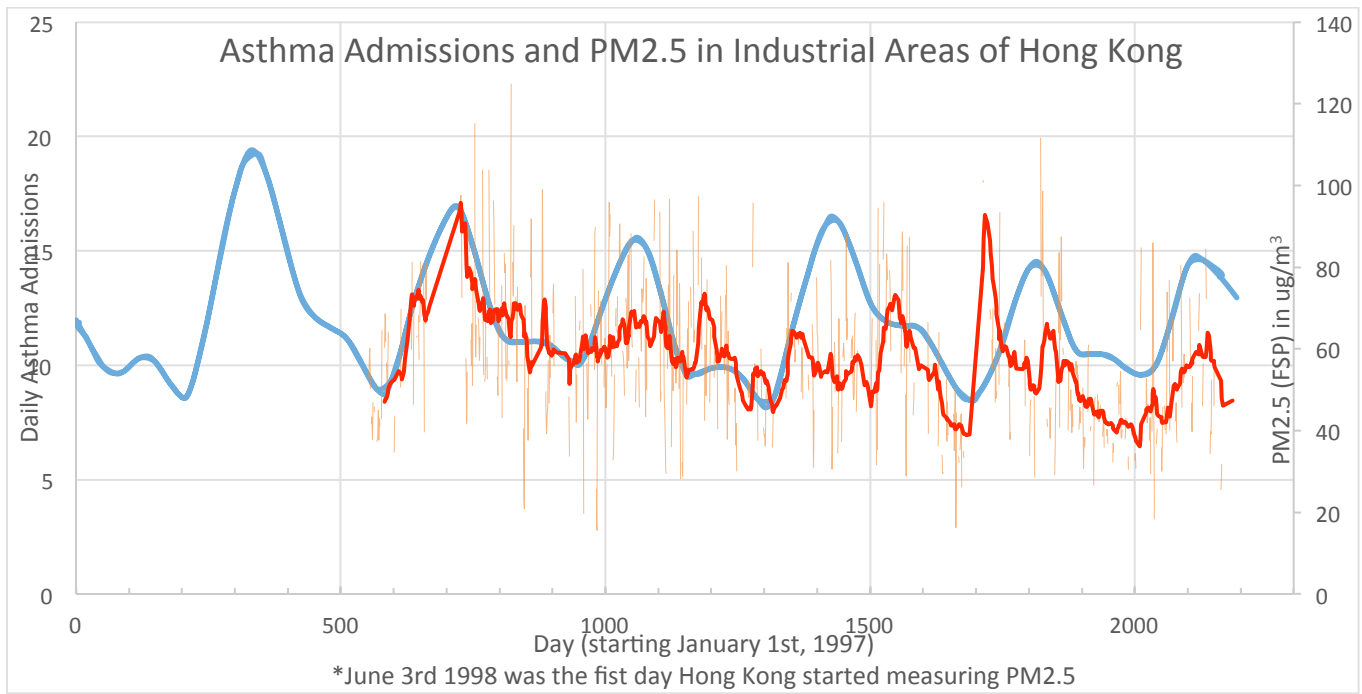


Figure 5: Time-series analysis of particular ambient pollutant displaying a null effect on daily hospital admission patterns

	PM10 (RSP) :	PM2.5 (FSP) :	NO <sub>2</sub> :
Correlation with Asthma Admissions:	0.17	0.29	0.31
Correlation with Total Hospital Admissions:	0.08	-0.06	0.19

Table 2: Quantitative significance of asthma-related incidences and air pollution quantities when adjusted for daily population densities effect on personal exposure

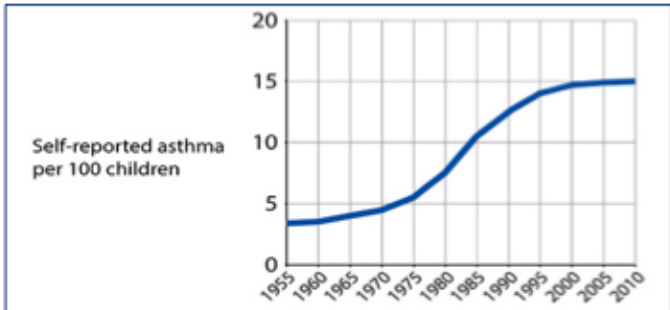
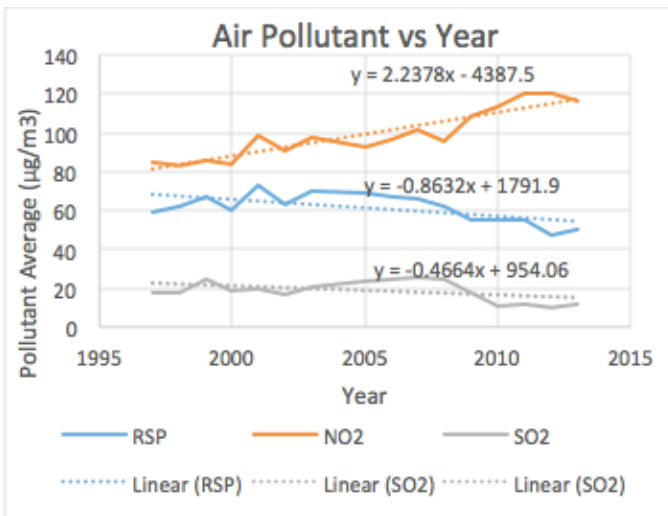


Figure 6: Time-series analysis of long-term trends of pollutant and adolescent asthma diagnosis rates in Hong Kong; overall increase of NO<sub>2</sub>, PM<sub>2.5</sub> (not shown due to limited data records), and asthma cases heighten the need for revised air pollution policies

	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Total
Respiratory problems-Student	340	412	1077	1032	1104	574	493	1235	1481	919	578	323	9568
Respiratory problems-Staff	337	375	358	415	430	600	662	591	514	464	432	485	5663
Skin (dermatitis) problems -	156	128	270	268	238	213	140	194	218	270	230	170	2495
Skin problems -Staff	160	143	130	148	107	114	141	127	138	157	168	220	1753
PM2.5 (µg/m3)	19	16.83871	12.9375	35.96667	39.12903	37.200	45.000	55.41935	34.17857	21.07578	16.8625	9.269946	
HKUST # of holidays	(Summer term) June 20 <sup>th</sup> July 1 <sup>st</sup>	(Summer Term-13 <sup>th</sup> )	(Fall term start on the 1 <sup>st</sup> ) Sept. 9 <sup>th</sup>	Oct. 1 <sup>st</sup> , 2 <sup>nd</sup>	0	0	(Fall term end on Dec. 19 <sup>th</sup> ) Dec. 25 <sup>th</sup> , 26 <sup>th</sup> Jan. 1 <sup>st</sup>	0	Feb. 19 <sup>th</sup> , 20 <sup>th</sup> , 21 <sup>st</sup>		April 3 <sup>rd</sup> , 4 <sup>th</sup> , 6 <sup>th</sup> , 7 <sup>th</sup>	May 1 <sup>st</sup>	May 25 <sup>th</sup> (Winter Term ends on 30 <sup>th</sup> )
Closed (with weekends)	28-8	31-8	29-10	28-8	31-8	30-10	28-8	30-8	28-8	26-8	30-8	29-10	
Days Clinic was open	20	23	19	20	23	20	20	22	20	18	22	19	246
Projected Number of Student Absences from doctor's note of leave request (R→T)	68 99	82 108	215 269	206 260	221 268	115 157	99 127	247 286	296 340	184	116 162	65 99	1914 2413
										238			

Table 3: Results from the HKUST case study on air pollution's effect on student absenteeism. Correlation between valid monthly (student majority was on campus for 75% of the month) air pollution levels and student absenteeism was 0.1 for PM<sub>10</sub>, 0.2 for PM<sub>2.5</sub>, and 0.3 for NO<sub>2</sub>.

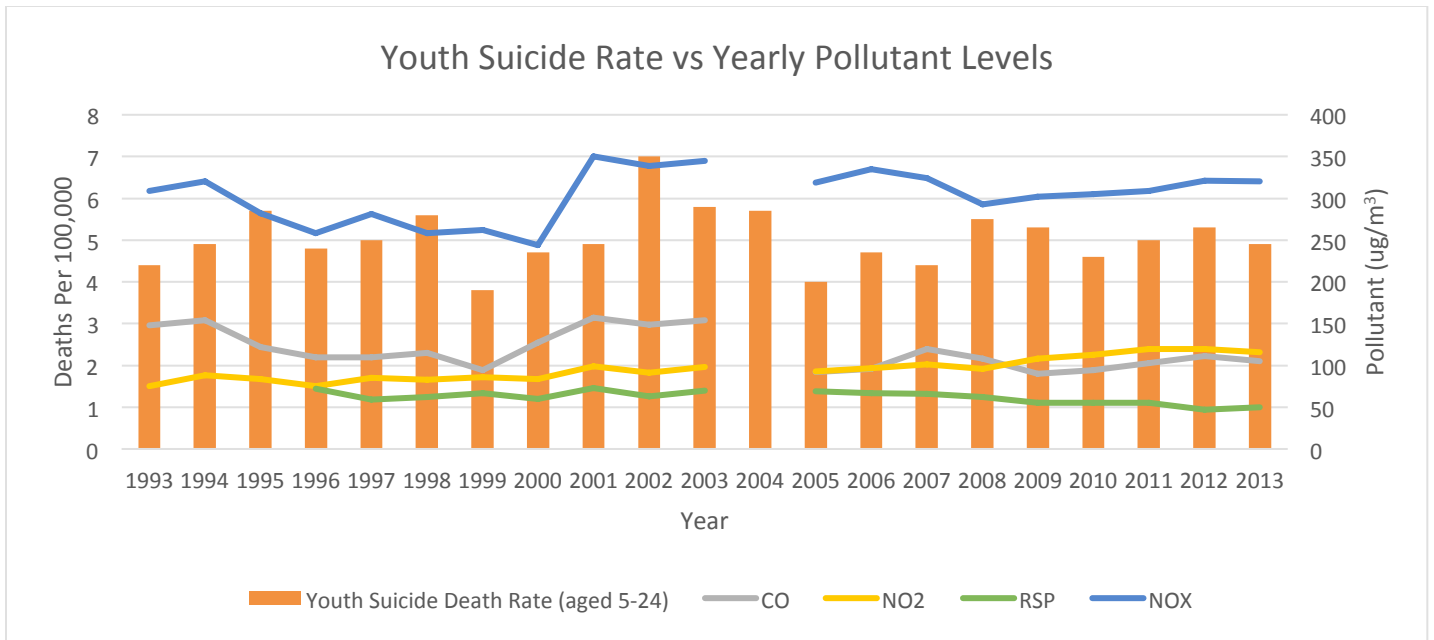
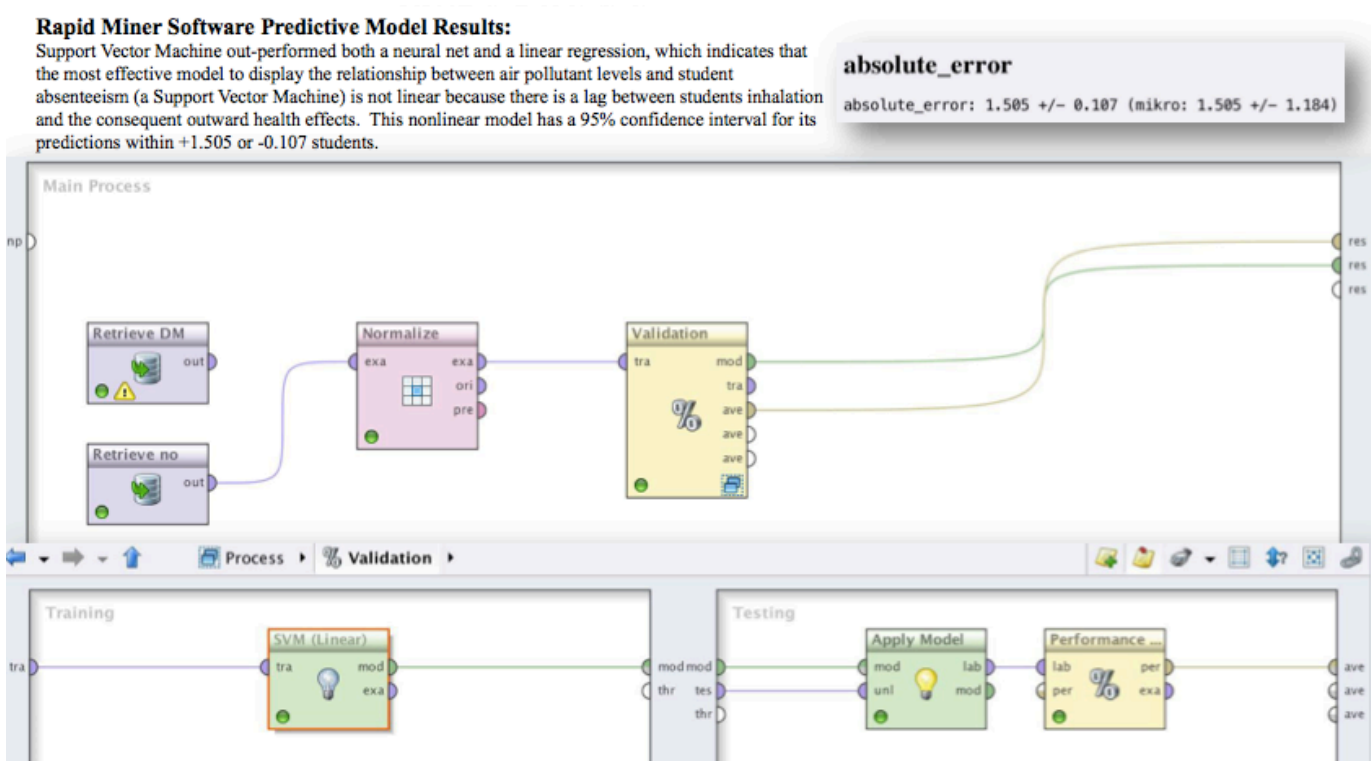


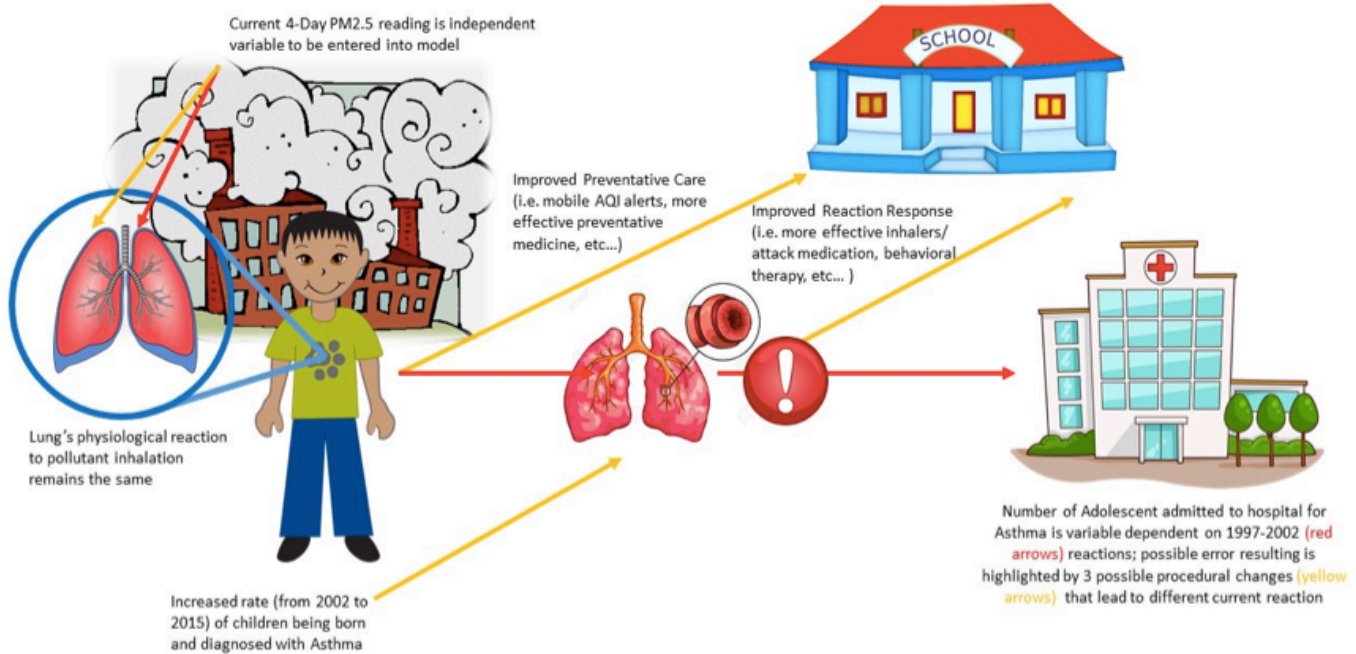
Figure 8: Time-series analysis of (available) yearly particular ambient pollutant levels and yearly youth suicide rates; 0.43 correlation with carbon monoxide and 0.27 correlation with nitrogen oxides.

**Rapid Miner Software Predictive Model Results:**

Support Vector Machine out-performed both a neural net and a linear regression, which indicates that the most effective model to display the relationship between air pollutant levels and student absenteeism (a Support Vector Machine) is not linear because there is a lag between students inhalation and the consequent outward health effects. This nonlinear model has a 95% confidence interval for its predictions within +1.505 or -0.107 students.



# Current Relevancy of Predictive Model

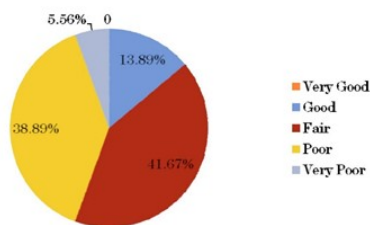


## Significance:

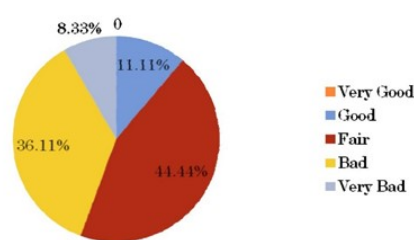
- Using past health data is reliable as human lungs have not adapted to the inhalation of chemical particles
- Recent asthma care improvement effects are nullified by recent increase in asthma diagnosis

## Student Questionnaire Results:

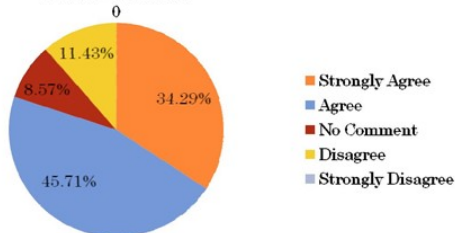
How do you comment on the current air quality of Hong Kong?



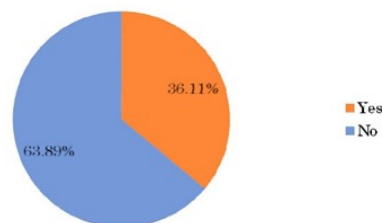
How do you comment on the government's policies to improve air quality?



How do you comment on the quality of air being a health concern?



Have you ever developed respiratory issues during periods of high smog?



From the questionnaires we can see that a mass majority of students think that the air pollution problem in Hong Kong is poor; however the awareness portrayed by these numbers could improve as only 10% of days in Hong Kong being below the AQI limits set by the WHO, the WHO would rate Hong Kong as having very poor AQI. Many adolescents are dissatisfied with the current policies on air pollution control by the government. The awareness of people to the relationship between their health and the environment is high but a disconnect still exists as more than one in ten students do not recognize AQI's relationship to health. Yet more than one third interviewees suffered from environmentally related respiratory diseases.

Figure 7: 100 sample size of adolescent student responses from Hong Kong University of Science and Technology

## Conclusion

From the statistical data, it is found that asthma is closely related to the deteriorating air pollution such that the hospital admission rate and death rates as a result of asthma attacks increases with the Air Pollution Level. It is also found that Hong Kong had quite a lot of people suffering from environmentally related respiratory disease as a result of the poor air condition in Hong Kong. The strong correlation presented in this study that reiterates the percentage increases of asthmatic admissions shown by the original study solidify the link between adolescent lung health and air pollution. In addition, Nitrogen dioxide and PM<sub>2.5</sub> presented the greatest link to an increase in hospital admissions. However, PM<sub>2.5</sub>'s effect became increasingly significant when the 4-day lag of its deep-airway lodging effects were accounted for. Although more studies should be done to exact the effects of air pollution on student absenteeism, the adverse health effects of air pollution are in turn affecting student attendance. Many students find it extremely difficult to attend class after being admitted to the hospital for asthma-related illnesses. The effect this absenteeism is having academic success should be quantified in future studies, although as discussed in the introduction there is extensive literature saying student grades and drop-out-rates increase almost linearly with number of missed school days. This effect that air pollution is having must be mitigated in the short-term; one way to accomplish this is by working to close the knowledge-action gap that exists for researchers, government, and affected individuals. This could be achieved through qualitative/quantitative research partnership between schools and healthcare. Apathy should not be a reason for inaction when the education and overall wellbeing of children are currently suffering because of it. If immediate reduction of air pollution is not possible then sustainable short-term initiatives should be considered. Possible initiatives include reduce mobile technology resources to increase communication between absent students, families, and teachers. Additionally, in-school behavioral supports to help students therapeutically reduce the effect of their asthma symptoms so they can stay at school should also be explored as a possible solution. The government's Health Authority Body should also launch campaigns and new technology to promote AQI awareness as well as mobile health alerts for the age and health-history specific populations given an AQI forecast. Moreover, people should be more aware of the close relationship between air pollution and asthma, such that they can carry out preventive measures for the sake of alleviating the problems of asthma.

Asthma is not currently curable but preventing triggers, such as air pollution exposure, can diminish its damage.

Careful planning and limiting of exposure to asthma triggers are the best ways to prevent asthma attacks.

Despite short-term initiatives it will be extremely difficult to negate the effects of air pollution on student health without directly addressing the levels of pollution. It is critical that the government of Hong Kong starts to set tangible air pollution reduction goals and work to meet them through incentivizing reduction for large companies and creating stricter environmental laws surrounding PM2.5 and NO2. Specifically, the government can pass and enforce more stringent rules controlling the emission of particles from vehicles and factories that contain these substances. Asthma can cause recurrent symptoms as well as missed school days, parents' missed workdays, and substantial stress on daily family life. Hospitalization rates for childhood asthma are high, and appear to be increasing.

The solutions to the asthma epidemic in Hong Kong will not likely lie in new medicines and therapies but in increased knowledge and preventative measures. Beneficial treatments for childhood asthma are already available. I feel that at least part of the solution lies in overcoming multiple obstacles in the receipt of effective care. Decrease the burden of asthma in Hong Kong through better understanding of the gaps in asthma healthcare, improving overall care for urban children who suffer from asthma, and developing sustainable models for asthma care that can be disseminated. Furthermore, Hong Kong's school staff members can play an important role in helping students with asthma manage their disease at school. Schools and their staff can work together with parents or guardians, students, and health care providers to minimize risk and to provide a healthy and safe educational environment for students with asthma. The benefits to students include better attendance; improved alertness and physical stamina; fewer symptoms; and fewer restrictions on participation in physical activities and special events, such as field trips, and fewer medical emergencies. Ultimately, good health and safety are prerequisites to academic achievement.

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