IMPACT OF METEOROLOGY AND ITS ASSOCIATION WITH THE SPATIAL DISTRIBUTION OF ASTHMA IN VADODARA CITY.

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CONCISE SUMMARY

The predicted effects for the environment and for human life are numerous and varied. The main effect is an increasing global average temperature. From this flows a variety of resulting effects, namely, rising sea levels, altered patterns of agriculture, increased extreme weather events, and the expansion of the range of tropical diseases (Krosnick *et al.*, 2000). From ancient times weather forecast has been major source for a layman to understand the atmospheric conditions. Based on these forecasts, one used to schedule his day-to-day activities and work accordingly. Earlier these forecasts were based solely upon the observations of sky.

Today, meteorologists rely heavily on computer models (numerical weather prediction), it is still relatively common to use techniques and conceptual models that were developed before computers were powerful enough to make predictions accurately or efficiently (Hardin, 2003 and Bronnimann *et al*., 2005). Meteorological phenomena are the observable weather events, which are bound by the variables that exist in the earth's atmosphere. They are heat, pressure, wind and moisture. All weather including pressure system, wind speed and direction, humidity, temperature and precipitation, ultimately results from the variable relationships of heat, pressure, wind and moisture. It is mainly the result of interactions between each of them with change in time. India is predicted to become the world's most populous nation by the year 2050. Industrialization and urban growth are now occurring at an unprecedented rate in this previously agrarian society (Chowgule *et al.*, 1998).

Asthma is a chronic inflammatory disorder of the airways, usually associated with airway hyper-responsiveness and variable airflow obstruction, that is often reversible spontaneously or under treatment (Cohn *et al.,* 2004). Allergen sensitization is an important risk factor for asthma. Asthma is often associated with rhinitis, an inflammation of the nasal mucosa (Busse and Lemanske, 2001). The recent substantial increase in the reported prevalence of asthma worldwide has led to numerous studies of the prevalence and characteristics of this condition (Eder *et al.,* 2006). Foremost among these are 2 major international initiatives that have collected data using validated questionnaires, one among children, the International Study of Asthma and Allergies in Childhood, (ISAAC, 1998) and the other among young adults, the European Community Respiratory Health Survey(Janson *et al.,* 2001).

Both prevalence and mortality from asthma appear to have increased in many parts of the world during a time when better asthma medications have been available to more patients suffering from asthma (Alderson, 1987).

Asthma has become more common in both children around the world in recent decades. The increase in the prevalence of asthma has been associated with an increase in atopic sensitisation, and is paralleled by similar increases in other allergic disorders such as eczema and rhinitis (Jarvis and Burney, 1998). The rate of asthma increases as communities adopt western lifestyles and become urbanised. With the projected increase in the proportion of the world's population that is urban from 45% to 59% in 2025, there is likely to be a marked increase in the number of asthmatics worldwide over the next two decades. It is estimated that there may be an additional 100 million persons with asthma by 2025.

Striking geographic variations in asthma prevalence are evidence of important variations in asthma susceptibility and equally important—and often dynamic—environmental determinants of asthma. Surveillance of asthma in North America, Western Europe, and Australia has demonstrated recent increases in asthma prevalence and mortality. Application of a standardized asthma surveillance methodology in 48 centres worldwide, the European Community Respiratory Health Survey (ECRHS), allows the most valid available comparisons of asthma prevalence and of determinants associated with asthma, including patterns of asthma therapy.

The environmental problems in India are growing rapidly. The increasing economic development and a rapidly growing population that has taken the country from 300 million people in 1947 to more than one billion people today is putting a strain on the environment, infrastructure, and the country's natural resources. Industrial pollution, soil erosion, deforestation, rapid industrialization, urbanization, and land degradation are all worsening problems. Air pollution has become a major concern in India in recent years both because it is now clear that large parts of the Indian urban population are exposed to some of the highest pollutant levels in the world (Smith, 1993 and WHO, 2000) and also because new studies around the world on the health effects of air pollution have increased confidence in estimates of the risks posed by air pollution exposures (Holgate *et al.,* 1999 and Lippmann, 2000). Overexploitation of the country's resources be it land or water and the industrialization process has resulted environmental degradation of resources. Environmental pollution is one

of the most serious problems facing humanity and other life forms on our planet today. A qualitative as well as a quantitative approach has been used to assess the impacts of climate change on human health. India is projected to become the world's most populous nation by the year 2050. As a result, further predicted increases in the prevalence of asthma will result in a marked increase in the number of asthmatics. For example, if the prevalence of asthma in the region increases by an absolute 2%, then this will result in at least an additional 20 million asthmatics in the region. (Chowgule *et al.,* 1998 and Gupta *et al.,* 2001).

India's per capita carbon dioxide emissions were roughly 3,000 pounds (1,360 kilograms) in 2007, according to the study. That's small compared to China and the U.S., with 10,500 pounds (4,763 kilograms) and 42,500 pounds (19,278 kilograms) respectively that year (Dharmendrasingh, 2011). The study said that the European Union and Russia also have more emissions than India. India has been ranked as seventh most environmentally hazardous country in the world. Indian megacities are among the most polluted in the world. Air concentrations of a number of air pollutants are much higher than levels recommended by the World Health Organization (Kandlikar and Ramachandran, 2000; Pande *et al.,* 2002 and Paramesh, 2002).

Some of the factors categorized as the risk factors of asthma are indoor air quality, health care, family history, and exposure to environmental tobacco smoke and other irritants. Air quality can be well related to both air pollution and the meteorological conditions prevailing in the area. It is observed that air pollution is a major cause for asthma either in its initiation or aggravation as studied and reported by various scientists all across the globe. (Holmen *et al.,* 1997; Norris, *et al.,* 2000; Schwartz, 2002 and Agrawal *et al.,* 2006).

The prevalence of asthma has increased markedly over the past 30 years. In developed countries, approximately 10% of adults and 15% of children have asthma. Most asthmatics are atopic, and they often have allergic rhinitis and/or eczema. The majority of asthmatics have childhood-onset disease. A minority of asthmatic pts do not have atopy (negative skin prick tests to common allergens and normal serum total IgE levels). These individuals, occasionally referred to as intrinsic asthmatics, often have adult-onset disease. Occupational asthma can result from a variety of chemicals, including toluene diisocyanate and trimellitic anhydride, and also can have an adult onset.

This increasing trend of asthma and other allergic diseases have become now a major concern and challenge for the coming century and generation (Baena-Cagnani, 2001). With the projected increase in the proportion of the world's urban population from 45% to 59% in 2025, there is likely to be a marked increase in the number of asthmatics worldwide over the next two decades. It is estimated that there may be an additional 100 million persons with Asthma by 2025. The highest Asthma prevalence rates are found in the United Kingdom (>15%) and New Zealand (15.1%) (Masoli *et al.*,2004).

In India, an estimated that 57,000 deaths were attributed to asthma in 2004 (WHO, 2004) and it was seen as one of the leading cause of morbidity and mortality in rural India (Smith, 2000). Though effective screening, evaluation, and management strategies for asthma are well established in high-income countries, these strategies have not been fully implemented in India as evidence had previously suggested that asthma is not to be treated independently but fitted into the general spectrum of respiratory diseases (Krishnakumar, 2003). Furthermore, even though medicines that treat asthma effectively are available at affordable costs, they rarely reach more than one per cent of those who would benefit from it (Krishnakumar, 2003).

There is limited asthma research currently going on in India and they are far from adequate to address the emerging demand (corresponding increase in disease burden). National Asthma surveillance data collection is currently limited, and this presents perhaps the most significant gap in asthma research in India. Therefore, to measure the extent of the problem in the entire population, there is a need for reliable population-based epidemiological studies in the context of its existing and potential economic impact.

Gujarat has a complex geomorphologic evolution, a very wide range of climatic variability and uniqueness of flora and fauna. Attempt to achieve faster economic growth is putting a progressively increasing pressure on environment. The policy of industrial promotion with liberal incentives did not discriminate enough about the type of industries or their demand on life supporting systems or the absorbing capacity of the environment. Gujarat is amongst the most industrialized states in India; and also leads in urbanization. Proactive and innovative efforts are required to optimize the use of natural resources. Most of the highly polluting industries in the list of 18, identified by the Central Pollution Control Board, can be found in Gujarat. Almost 80% of the major and medium industries and 65% of the small-scale

industries are located in the golden corridor stretching from Vapi to Mehsana. The stretch also boasts of 84% of the units manufacturing highly hazardous chemicals. Most of the water polluting industries [major and medium] are set up in the golden corridor, Ahmedabad accounting for 154, followed by Surat [89], Bharuch [74], Valsad [68], Vadodara [53] and Mehesana [25].The golden corridor traverses the basins of Sabarmati, Mahi, Narmada, Tapi and Damanganga rivers which among them represent 78.1% of the available surface water resources [85.54% of the total utilizable surface water resources] of the State. The implications of both the composition and location of industries in Gujrat for its water resources are obvious. These factors have made Gujarat 'one of the most polluted states of India'.

Vadodara (Baroda) is one of the mega cities of the state and the financial and commercial centre as well as a major industrial port. It is the state's most rapidly growing mega-city, with a projected population of 15 million in the year 2000. The city gains over 250,000 rural-to-urban emigrants annually. Vadodara lies on a narrow peninsula running north to south, connected to the mainland at the northern tip, constricting the geographic spread of its growing population situated at approximately 22°18′N 73°11′E. Sulphur reductions in fossil fuels in recent years have helped reduce ambient sulphur dioxide levels, but the increasing density of motor vehicles contributes to rising concentrations of total suspended particulate. ''In the last few years the topography of the state has changed because of large-scale development works—laying of canals and railway tracks, construction of new colonies. The flash floods, we believe, were caused by changes in the topography,'' Vadodara city was once known as the City of Gardens.

Our first aim was to find the baseline trend and correlation between air pollution and meteorological parameters for Vadodara city for 2005 to 2007. Meteorological records was collected for the previous three years so as to gather the baseline data and uncover the correlation between air pollution and meteorological parameters using source receptor modeling and shaft diagrams for Vadodara city.. The observations were made to study the annual as well as the seasonal trend. It was observed that annual and seasonal variations of the conditions favorable to high pollution level and the definition of an area's micro climate in terms of air pollution is strongly supported. It can be established that such statistical analysis will help in predicting the air quality for pollutants in terms of meteorology. The

analysis and results obtained from the present study is not only important for interaction of meteorological and pollutants, but also for urban planners and decision makers. **(Chapter I).**

The questionnaire used in the study had been aimed at collecting information on the respiratory symptoms and for establishing the prevalence of asthma, COPD and Rhinitis. As far as the questionnaire administration was concerned, random sampling was done for a population of 1000 of which only 792 responded correctly as required in the questionnaire. Further, the specific criteria of age, sex, education and occupation were taken into consideration. The age groups were broadly classified as 1-20 years; 21 to 40; 41 to 60; and 61 and above. The survey was done in 2008 and conducted over approximately 12 months.

Respiratory illness in general and asthma in particular was explored by questionnaires and depending on the clinical symptoms they were categorized for Rhinitis, COPD and Asthma. For purpose of distribution analysis, descriptive parameters such as the means, standard deviation and percentage were used. Gender and age were used to create the subgroups for the entire study population. Prevalence of the asthma, rhinitis and COPD and individual respiratory symptoms in the identified groups were calculated in percentages as the number of subjects categorized as having asthma, rhinitis of COPD divided by the total number of subjects..

Out of the identified patients for total respiratory illness in the city, it was observed that in males the prevalence of COPD was 38%, Rhinitis 35% and Asthma 27% respectively. In case of females, however it was found to be a reverse trend where it was 36% Asthma, 35% COPD and 29% Rhinitis respectively. Out of all the three illness it was found that prevalence of rhinitis was higher in the age group of 1 – 20 years (42% in Females and 40% in Males), in age group 21 – 40 years prevalence of Asthma was higher in females (29%) and Rhinitis was higher in males (37%), in age group 41 – 60 years, prevalence of Asthma was higher in both males (35%) and Females (42%). For the age group 61 and above it was found that occurrence of Asthma again was higher in both males (27%) and females (19%). **(Chapter II).**

Having known the past trend for the interaction between meteorological parameters and pollutants and the occurrence ratio of asthma in the city, our next aim was to find the association of meteorological variables and pollutants with the incidence of respiratory illness in relation with the medical sale in vadodara. Along with 8 meteorological parameters and 3

Pollutants, sale of 7 Respiratory medicines (i.e B. Inhalant Preparations, B. Inhalers, Inhaler Devices, B. Liquids, B. Injecta, B. Solids and B. Others) were considered in this study, the data was obtained from ORG department for year 2005 to 2010. These 18 parameters were then applied on SPSS 12.0 and the trend of interdependence for last five years was analyzed. In this study, increase in the medical sale was found dependent on distinct meteorological factors as well as pollutants and that each factor was acting as trigger for the increase in the specific medical sale proving to be the direct link between the triggering factors and respiratory illness. On detailed analysis it was found that wind speed, relative humidity, vapour pressure, cloud cover and RSPM had a greater influence with the sale of medicine and occurrence of the respiratory illness **(Chapter III).**

With the preview of having the meteorological factors responsible for the asthma exacerbations in the city, it was then decided to find the season and age specific trend of the exacerbation. Hence, our next aim was to find the correlation between asthma exacerbation with respect to alteration in lung function capacity and environmental triggers. Pulmonary function tests are a group of tests that measure how well the lungs take in and release air and how well they move gases such as oxygen from the atmosphere into the body's circulation (Pellegrino *et al.,* 2005).

A spirometer is one such device used to measure lung function. It is a powerful tool that can be used to detect, follow, and manage patients with lung disorders. The use of spirometry helps in detecting cases at an early stage when intervention may prevent further progression of the disease. Spirometric tests are performed on a large scale with different objectives for example, it gives additional information to help establish a clinical diagnosis in a patient and assess the prognosis in a patient. It is used in diagnosing asthma or to periodically re-assess how the asthma treatment is effective. The clinical significance of spirometry in disease was recognized more than sixty years ago, but in the last decade little attention has been devoted to its practical application. Vital capacity is the maximum amount of air that can be inhaled or exhaled from the lung. Forced Vital capacity is defined as the amount of air which can be forcibly exhaled from the lungs after taking the deepest breath possible. FEV1 is the maximal amount of air that an individual can forcefully exhale in one second. It is then converted to a percentage of normal. FEV1 is a marker for the degree of obstruction with asthma (Scott *et al.,* 2003).

Over the period of four years (2007 – 2010) the total numbers of the recorded patient's visits were 5202, of which 3171 were males and 2031 were females. Out of the total 3171 males 17.5% were reported to be asthmatics. On the other hand of the documented 2031 females 42% were found to be asthmatics, indicating the dominance of the female gender suffering from asthma in vadodara city. The onset of asthma dominance was observed in age group of 31 plus in males as well as females and persisted till the age group of 60. Irrespective of the gender of all the age groups the maximum occurrence of the asthmatics documented were belonging to the age group of 41-50. The next objective of the present study was to assess the association between air pollution, meteorological conditions in a panel of adult group of female patients suffering from asthma, living in Vadodara city.

To achieve the precise objective, the entire study further was divided into two parts (Part A & B). Study in Part A was to find the correlation between the lung function values and environmental factors whereas the study in part B was to find the spatio-temporal distribution of asthma patients in Vadodara city. Results in part A study depicted that lung functions had shown a remarkable association with the meteorological factors and pollutants. However, the sensitivity of each triggering factor varied seasonally with each environmental factor and showed significant response to all the recorded lung functions. When seasonal lung functions of the selected asthma patients were monitored, there was a distinct correlation observed.

Here, all the three lung functions expressed the response differently in the summer season. Also, individual seasonal analysis showed maximum participation of the triggers in the summer season, of all the years studied, 2008 showed the significant alterations in the lung functions, FVC, FEV1 and PEF showing a significant positive correlation with RH and VP. Monsoon and winter were not showing strong correlation compared to summer inspite of having the maximum asthma exacerbations in winters (42%) followed by monsoon (33%). Having the summer asthma exacerbations showing positive significant participation with all environmental factors, our next aim was to find age wise summer correlation with the asthma exacerbation within 41 to 50 years in females. It was found that females at the age of 42, 43, 45, 46 and 48 were mainly affected by asthma exacerbations in summer.

Results in part B, depicted that seasonal differences occurred between spatio- temporal plots considered in different seasons. In this study our aim was to look into the pollution pocket as well as the wind rose pattern in Vadodara city. The frequencies of specific wind directions as well as the wind speeds varied from year to year due to the frequency of weather patterns that can affect an area. There are, however, some important differences that can be readily

observed in the wind roses. In summer season (2007 – 2010) it was found that majority of females were residing in and around the pollution pockets which was not the case in monsoon and winter season. The alterations in the lung functions were observed in the monsoon and winter season also but it was not found to be correlating with the identified pollution pockets for the respective season, probably suggesting that the monsoon and winter season exacerbations were not due to the environmental triggers but they may be due to the respiratory viral illness or genetic inheritance. **(Chapter IV).**

The asthma patients were then monitored based on the suggested management plans given to them to find the effectiveness of the management strategies to reduce the trauma of the disease in the affected identified patients. We provided to all patients a written asthma action plan that included daily management and recognizing and handling changes in PEF measures. A written asthma action plan was particularly recommended for patients who belonged to age group 41 to 50 years in females.

Total forty six patients were selected for asthma management strategy out of which twenty one subjects had dropped out of the study for various reasons and were considered as non-attenders, or group NA. Rest Twenty-five patients with summer asthma exacerbations were enrolled for the management programme. They were the same group of patients who had shown the correlation with the specific environment. These remaining 25 patients took part in an asthma education program including an action plan based on PEF monitoring and were asked to measure their PEF morning and evening; they were given a peak flow meter and a diary card. Patients involved in the study were then taken for the individualized asthma management strategy which included an hour session wherein they were instructed to adjust the treatment according to their PEF values. At each follow-up visit, reinforcement regarding the usefulness of PEF monitoring was given. The specialized physician also reviewed the diary card to check whether the patient had increased his asthma medication when PEF dropped.

During a 1-year randomized prospective study, participants were asked to measure morning and evening PEF throughout the year. The best of the three consecutive measurements of PEF values had to be recorded in their diaries. They all participated in an individualized asthma education program that covered the following issues of asthma triggers, criteria of

good asthma control, usefulness of PEF monitoring, and management of asthma exacerbations according to PEF values.

A patient's best peak expiratory flow was determined by use of the peak flow meter twice daily when the patient's lung function was at its best. From that baseline, the patient's 'zones' were then determined as Green Zone - 80 - 100 % of patient's personal best PEF, Yellow Zone - 50 - 80 % of patient's personal best PEF and Red Zone - less than 50 % of patient's personal best PEF. Once the individual patient's zones were defined, they were instructed on actions to take for each zone. PEF measures could also be used to help diagnose asthma, assess the influence of environmental factors on asthma, and document changes in asthma therapy. Along with the peak flow meters we provided the selected group of patients with a written asthma action plan that included instructions for daily management and recognizing; handling worsening of asthma along with changes in PEF measures.

They were appraised on how to monitor signs and symptoms so they can recognize early signs of deterioration and take appropriate action, particularly since many fatal asthma exacerbations occur out of hospital (Krishnan *et al.,* 2006). They were taught by the physicians how to adjust their medications early in an exacerbation (Kelly *et al.,* 2002b) and when to call for further help or seek medical care. They were asked to opt for medical help earlier if the exacerbation was severe; treatment did not give rapid, sustained improvement; or there was further deterioration. In our study, even though patients were instructed in why to use peak flow meters and how to use them properly, their compliance with monitoring was not optimal. Throughout the study period, the average compliance of the patients with PEF record maintenance decreased from 71% of measurements at 1st month, to 58% at 6th month and finally to 30% at 12th month. When compared with a usual care group, the experimental group showed improvement in compliance and reductions in asthma exacerbations and visits to chest physicians. At the end of 1 year, 26% of the patients achieved total control on their asthma exacerbations (i.e., the absence of any sign or symptom of asthma), and 52% had achieved well controlled asthma. **(Chapter V).**

The present study proves undoubtedly that there is an increasing incidence of asthma and a major percentage of the cases show direct correlation with environmental factors. The scientific evidence presented in this study coupled with knowledge of individual trigger factors could help the health care provider design personalized management strategies for the patient. The medical care provided should be cost effective, using local

resources. The main goal of treatment should be prolonged control of symptoms, prevention of potential adverse effects and should take into account the expected future risk to the patients such as exacerbations, accelerated declined lung function. Furthermore, such initiatives help in developing patient/doctor partnership which in turn helps in identifying and reducing exposure to risk factors and therefore achieving better disease control. Self management plan which includes self-monitoring effectively helps individuals in controlling the disease. Such initiatives bring together the medical practitioners, academicians, health care professional and patient groups to translate the appropriate guidelines.

Future studies can be directed to explore multiple factors like ethnicity, socio-economic status, allergy, pollens triggering activity, stress etc. and their role in asthma exacerbations.