CHAPTER IV

A CORRELATION BETWEEN METEOROLOGICAL FACTORS. POLLUTION LEVEL AND ASTHMA EXACERBATIONS IN VADODARA CITY – 2007 TO 2010

4.1 INTRODUCTION:

Climatological and medical communities are increasingly concerned that climate change is likely to have wide-ranging impacts on human health. Climate Change is now a reality and assessing the impact of climate change on human health is a vital task for scientists in the field of environmental – health research. Bronchial asthma continues to have a major impact on the public health globally (Krosnick *et al.,* 2000 and Bronnimann *et al.,* 2005) India is a subcontinent with different geographical, racial, cultural and economic groups. Therefore to know the influence of various geographic locations, socio-economic groups, site specific meteorological conditions and pollution concentration level on asthma and other respiratory illness is important. Increasing global temperatures affect the seasonal patterns of both manmade and natural air-borne particles such as pollens, both of which are the triggers of asthma (Hardin, 2003).

Number of investigators have ascertained links between asthma symptoms/admissions and particular atmospheric situations. Weather has a dual role, affecting the asthmatic through direct and indirect means. Among direct influences is rapid meteorological fluctuation, such as the onset of cold weather in the winter, which appears to be associated with decreased lung function in asthmatics (Krosnick *et al.,* 2000; Hardin, 2003 and Bronnimann *et al.,* 2005). Increased visits to hospital emergency rooms were found to be associated with decreases in temperature, especially during and after the first and second onset of cold periods in the fall; another study incorporating a subjective identification of weather events found nearly all asthma epidemics in both New Orleans and New York City were preceded by the passage of a cold front followed by a high pressure system (Alderson, 1987; Chowgule *et al.,* 1998; Roemer *et al.,* 2000 and Mount Sinai Medical Center, 2009). Asthmatic behavioural responses are an important indirect effect of weather. Increases in emergency clinic admittances during the first onset of cool or cold weather in fall often occurred in United States cities with the first seasonal use of indoor heating (Alderson, 1987; Chowgule *et al.,* 1998; Roemer *et al.,* 2000 and Mount Sinai Medical Center, 2009). This seasonal increase could be related to the transport of dust particles accumulating in heating systems used for the first time since the previous spring (Mount Sinai Medical Center, 2009).

These studies use simple regression and/or comparative techniques, and there is a notable lack of sophisticated climatological modelling. The goal of this research is to utilize recently-developed procedures which evaluate this simultaneous impact of the entire suite of meteorological elements on the asthmatic. This study incorporates a "synoptic climatological approach" to categorize daily weather into air mass types, which are homogeneous bodies of air with distinct thermal and moisture characteristics (Rao and Rao, 1989). While the synoptic methodology employed here is site-specific, similar categories can be identified at different locations. This procedure has been used primarily by climatologists in a number of weather/health evaluations to identify unhealthful weather situations and the individual parameters within them that contribute to health problems (Peavy *et al.,* 1985; Seetharam and Jeena, 2002 and Guastella and Knudsen, 2007). Considering the findings of previous researchers, this study makes an assumption that certain air masses, such as those possessing cold temperatures and high barometric pressure in the fall, will be highly correlated with increased asthma admissions. However, it is also expected that other air mass types will be responsible for increasing admissions, and the use of a synoptic climatological approach will contribute considerable insight to an array of asthma/weather interactions.

Certain air pollutants have been shown to be associated with increased asthma admissions to hospitals (De, 2000), and weather can have an indirect effect on these admissions by affecting the atmospheric concentration of such pollutants. It is plausible that stagnant weather conditions permit the buildup of atmospheric pollutants which exacerbate the asthmatic condition (Mount Sinai Medical Center, 2009). The synoptic climatological approach used here permits an evaluation of the influence of atmospheric pollutants on admissions within each weather situation. Another potential indirect effect of weather on admissions involves air-borne allergen concentrations; again, stagnant weather conditions may contribute to high spore concentrations. Several studies have reported on the coincidence of asthma epidemics with thunderstorms (Ravindran, 2000; Douwes, *et al.,* 2002; Landrigan, *et al.,* 2002; Prasad, *et al.,* 2003 and Krishnakumar, 2003) and the unhealthy allergen conditions that result. The synoptic climatological procedure appears well-suited to evaluate asthma hospital admission variation as impacted by the various factors discussed above.

The cascading effects of variable rainfall and higher temperatures will touch most aspects of life in the region. Weather extremes and greater fluctuations in rainfall have the capacity to adversely dent the region's productive areas and comparative advantage. Food security, health, livelihoods, access to basic services, energy, and shelter could all be affected. Climate change has the potential to reverse the development gains that have been achieved by South Asia over the past decades. (Ramalingam *et al.*, 2008)

In South Asia, heat waves, flooding, and increased intensity of tropical cyclones and storm surges all pose threats to human well being and health. Possibly the greatest health impacts could be those associated with population dislocation and displacement. People displaced internally or across borders are vulnerable to disease. Mental health impacts of extreme climate events and disasters present another public health challenge. The most common consequences of severe weather events, such as floods and cyclones, include anxiety, depression, and post-traumatic stress disorder.

The monsoon is the most significant climate event as it carries over 70 percent of the region's annual precipitation in only four months. Because of the dominance of the monsoons, the region's climate exhibits the highest seasonal concentration and variability of rainfall in the world. If climate projections are indicative of future trends, the risks associated with water-related climate variability are likely to intensify and worsen. Monsoonal rainfall over India has decreased by approximately 5 to 8 percent since the 1950s, which might contribute to more intense, longer, or more widespread droughts (Chung and Ramanathan, 2006).

Environmental changes are likely to decrease agricultural productivity and alter ecosystems in ways that will lead to a reduction in the food supply and an increase in vulnerability to outbreaks of infectious diseases, both water and vector borne. The prevalence of diseases associated with air pollutants and aeroallergens is also predicted to increase with changes in the hydrologic cycle and increases in ambient temperature. With increased temperatures, ground-level ozone may be expected to increase (Hu *et al.,* 2011). Ground-level ozone is a respiratory irritant, and mortality may therefore increase further on hot days. Specific characteristics of urban centres, including the capacity of certain buildings to retain heat and the relative lack of vegetation, contribute to further increases in temperatures that persist into the evening time. This 'heat-island' effect may be expected to further increase the heat stress suffered by city dwellers.

Indoor temperature and humidity are important to public health. Moderately high temperatures and humidity in buildings have been associated with increased dwellers distress, perceptions of poor indoor air quality (Berglund and Cain, 1989 and Fang *et al.,* 1998), unwanted tenants complaints (Federspiel, 1998) and adverse respiratory health symptoms (Mendell *et al.,* 2002). The ability of buildings to mitigate the heat and moisture impacts of climate change indoors, particularly for susceptible populations, is therefore a concern. Approximately 47 percent of homes are estimated to be sufficiently damp to result in respiratory affects in those exposed and are estimated to be responsible for 21 percent of current asthma cases in the U.S. Moisture and dampness in schools and office buildings are also associated with respiratory effects in occupants (Mudarri and Fisk, 2007).

As a well known fact, dampness and mold are associated with asthma and asthma-like respiratory symptoms. However, condensation and dampness are functions of relative humidity (RH) and not just absolute humidity. It was previously noted that with climate change, indoor temperatures are likely to rise along with outdoor temperatures. This rise in indoor temperatures will, to some extent, counter the rise in absolute humidity and tend to mitigate against the rise in RH. Thus, the impact of increased humidity is assumed to be relatively minor.

Asthma is an inflammatory disorder of the airways, which causes attacks of wheezing, shortness of breath, chest tightness, and coughing. When an asthma attack occurs, the muscles surrounding the airways become tight and the lining of the air passages swells. This reduces the amount of air that can pass by.

In sensitive people, asthma symptoms can be triggered by breathing in allergy-causing substances (called allergens or triggers). Common asthma triggers include:

- Animals (pet hair or dander)
- Dust
- Changes in weather (most often cold weather)
- Chemicals in the air or in food
- Exercise
- Mold

- Pollen
- Respiratory infections, such as the common cold
- Strong emotions (stress)
- Tobacco smoke

Aspirin and other nonsteroidal anti-inflammatory drugs (NSAIDs) provoke asthma in some patients.

The roles of meteorological or environmental factors in the development of respiratory disease have been proved by various observations, medical practice as well as medical reports since the age of hipocrates. General characteristics of the weather such as temperature, atmospheric humidity, wind direction and air pollution can influence the development of respiratory diseases (Jaklin *et al.*, 1971; Fielder, 1989; Goldstain, 1980 and Beer *et al.*, 1991). The influences of weather elements on mortality as well as the connection of the meteorological parameter and respiratory diseases have been widely studied in the related literature.

Previous studies have proved the direct co-relation of the pollutants and meteorological factors with the medical sale for respiratory illness. The aggravation of respiratory illness is related to daily variations in air quality. The increase in medication use with altered meteorological factors and pollution concentration thus proved to be a marker for knowing the exacerbations of respiratory illness. Given the increased prevalence of these diseases, the clinically identified and approved patients history will help in understanding the occurrence of the disease effective predictions would benefit a large segment of the population. As the link between triggering factors in the form of meteorology as well as the pollutants thus is an indirect evidence to prove the prevailing condition of the illness and also indicate that it may be appropriate to examine severe respiratory illness symptoms separately. Exposure to air pollution is a significant public health hazard predominantly affecting rural and urban communities in developing countries. There is consistent evidence that exposure to such triggers increases the risk of respiratory diseases.

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 diagnostic 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. Spirometer determines several aspects of lung function including:

- Vital capacity
- Forced expiratory volume (FEV1)
- Peak expiratory flow (PEF)

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 (Kitch *et al.*, 2004):

* FEV1 greater than 80% of predicted= normal
* FEV1 60% to 79% of predicted = Mild obstruction
* FEV1 40% to 59% of predicted = Moderate obstruction
* FEV1 less than 40% of predicted = Severe obstruction

Normally FEV1 = 70-80% of the FVC. Airflow obstruction is diagnosed if FEV1 is <65% of the FVC. Patients with obstructive patterns are more likely to respond to bronchodilator therapy. The FEV1 can then be used to assess the response. It is also used to diagnose asthma (15-20% variability in FEV1), to assess the severity wherein if the FVC declines, it is due to air trapping indicating severe asthma. FEV1 and FVC are also useful to monitor the condition and response to therapy. (Masson *et al.*, 2005) It is hence generally recommended by the chest physicians that the FEV1 is measured seasonally. Peak expiratory flow varies with age and gender (Stanojevic *et al.*, 2008).

The correlation between severe asthma attacks and weather conditions such as thunderstorms has been known for some time. However, the effect of local weather on the measured values of lung function on a daily basis has not been investigated (Cobern, 2005). Hence, in the present study an attempt is made to find out the correlation between the lung functions and environmental factors. Once the correlation has been documented, our next aim was to identify the area in which the pollutant precipitations have occurred and further establishing the direct correlation with the occurrence of asthma for Vadodara city.

4.2 MATERIALS AND METHODS:

4.2.1 Study parameters:

On the whole, 8 meteorological parameters, 3 Pollutants and 3 lung functions were considered in the present study.

- The 8 meteorological parameters are: Height of Lowest layer, cloud cover, Maximum temperature, Minimum Temperature, Wind speed, Rainfall, Relative humidity and Vapor pressure. The data was collected for 4 years i.e. 2007 – 2010 from the in-house instrument which was confirmed with the Indian Meteorological Department (IMD), Ahmedabad.

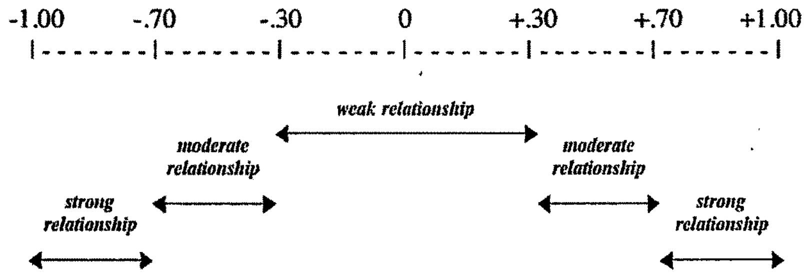
- Data for 3 Pollutants viz., SO_2, NO_x and RSPM (Respirable Suspended Particulate Matter) level of city was acquired from the regional office of GPCB (Gujarat Pollution Control Board).

- Spirometry tests were used to analyse the lung functions (FVC, FEV1 and PEF). The total number of visits to chest physician was categorized into Normal patients, Patients suffering from Respiratory illness and patients suffering from asthma based spirometer observations made by the doctor. Each of this group was then categorized into age and gender.

4.2.2 Application:

- These parameters were then applied on SPSS 12.0, software termed as Statistical Package for Social Sciences version 12.0 to conduct the Principal Component Analysis for the Meteorological parameters, Pollutants and Lung functions. Here the factor analysis study was performed and the extent of interdependence among these parameters and the trend of interdependence for last four years were analyzed.

- The level of significance was carried out using bivariate Pearson Correlation. The Pearson's correlation is used to find a correlation between at least two continuous variables. The value for a Pearson's can fall between 0.00 (no correlation) and 1.00 (perfect correlation). Other factors such as group size will determine if the correlation is significant. Generally, correlations above 0.80 are considered pretty high.



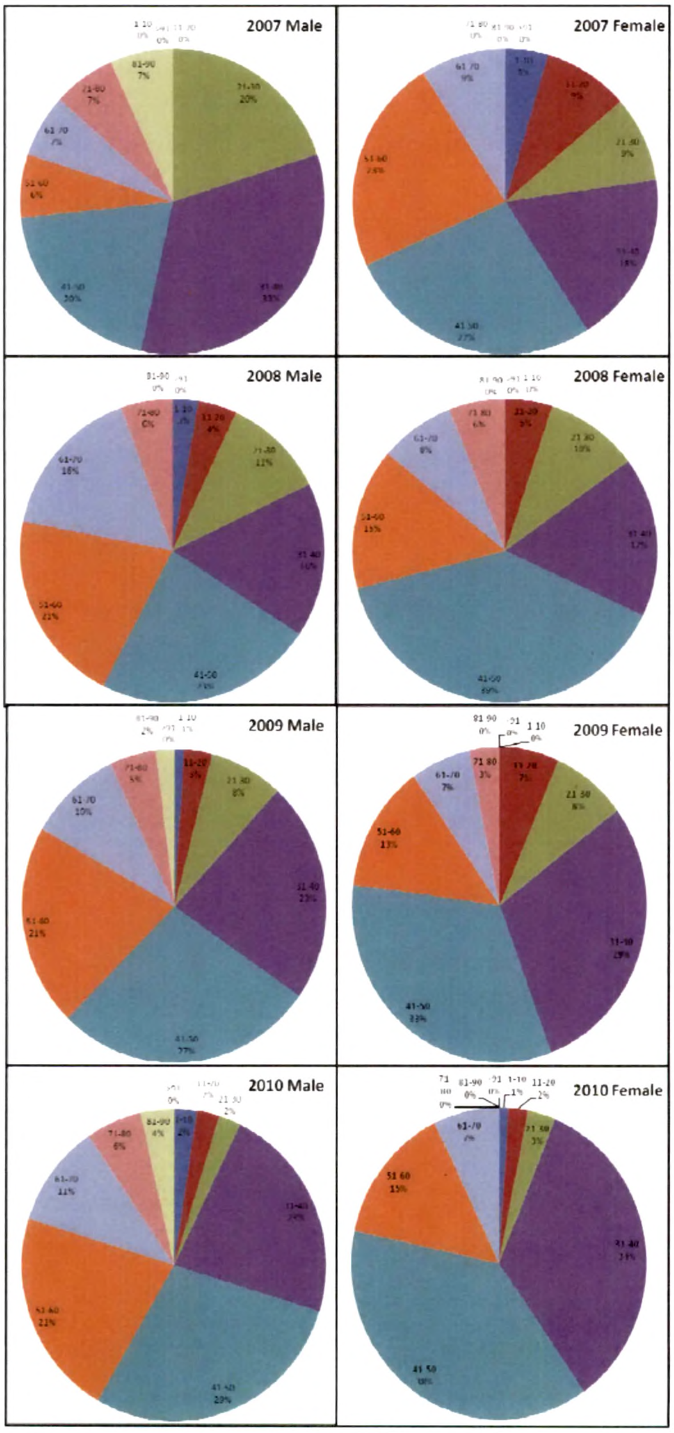
- Hourly Wind speed and wind direction data was implied on the Lakes Environmental WR Plot Software to get the Wind rose diagrams.

- Hourly Wind speed, Wind direction, Temperature, Stability and Urban Rural mixing height data was used in ISCST3 models which were then mapped using SURFER.

4.3 RESULTS & DISCUSSIONS:

Having established fact of an increasing trend in the asthmatics in Vadodara city (Chapter 2), in consent with the clinician the clinically identified asthma patients were taken as a sample size. The sample was collected from various clinics as well as the camps organised by chest physicians and CIPLA pharmaceuticals in and around Vadodara city. The approval of the patients was taken prior to recording their clinical information. Over the period of four years (2007-2010) the total numbers of the recorded patients visits were 5202, of which 3171 were males and 2031 were females. The recorded patients were then categorised gender (Male and Female) as well age wise (1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80 and above 81 age groups). Out of the total 3171 males 17.5% were reported to be asthmatics. Whereas of the documented 2031 females 42% were found to be asthmatics, suggesting the dominance of the female gender suffering from asthma in Vadodara city. After age 10, when the airway diameter/length ratio is the same in both sexes, probably because of changes in thoracic size that occur with puberty in males but not in females (Rosenthal *et al.*, 1993a; Rosenthal *et al.*, 1993b and Marco *et al.*, 2000) More females than males develop asthma during puberty and thereafter, so the prevalence of adult asthma becomes higher in females than in males. Age, gender and year wise distribution of the asthma patients is presented in (**Fig. 4.1**). In males maximum number of asthmatics were in age group **31 – 40** in 2007 (33%), **41 to 50** in 2008 (23%), 2009 (27%) and 2010 (29%). Whereas in case of females it was maximum at the age **41 - 50** in all the four years i.e 27% in 2007, 39% in 2008, 33% in 2009 and 38% in 2010. 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**. Studies have reported that gender is one of the important factors associated with asthma (Chhabra *et al.,* 1999). Asthma is twice as common in boys as girls in the paediatric population. However, by the end of adolescence, women have a greater prevalence of asthma than men (Redline and Gold, 1994; Singh *et al.,* 1999 and Wormald, 1977). Studies on acute asthma have also reported that women were almost twice as common as men, and women's increased likelihood of indoor environmental exposures is the probable causative factor. There is increasing evidence that differences in asthma morbidity by gender may be biologically driven. In the present study a clear cut distinction as well as dominance of asthma was reported in females with the age group between 41 to 50 which are in aggrement with the studies done earlier by Blumenschien and Johannesson (1998); Mancuso *et al.,* (2001); McColl *et al.,* (2003); Mancuso and Peterson (2004); Kannan and Rafshad (2011); Santhosh and Naveen (2011); Mithani and Monteleone (2011).

Fig. no. 4.1: Age Wise Occurrence of Asthma In Males And Females:



A. Correlation between the Lung Function Values and Environmental Factors:

Once documenting the most dominant age group of the females, further, the next objective of the present study was to assess the association between air pollution, meteorological conditions in a panel of adult female patients suffering from asthma, living in Vadodara city.

To understand asthma seasonality with respect to the meteorological and environmental variables, individual age group lung functions were documented.

Several comprehensive literature reviews have summarised the evidence for environmental factors but has not addressed the interplay among different kinds of exposures due to limitations of the analysis. Thus, while the body of environmental research on this subject has demonstrated that asthma can be affected by multiple factors, integrated approaches have not been used to examine the combined effects of environmental exposures acting together. The component analysis for summer revealed that the lung function variables were positively correlated with **CC** and **SO_2** concentration levels in 2007, whereas in 2008 it was found to be correlated with **LL**, in 2009 with **VP, RH, Wind speed** and **RSPM** and in 2010 was found to be correlated with **RF, RH, VP, CC** and **wind speed**. The descriptive analysis for summers depicted that the FVC values were varying from 2007 to 2010. The FVC and FEV1 values were relatively low for 2008 as compared to other years. The FVC values ranged from 1.54 Lit. to 2.53 Lit in 2007, 1.92 Lit. to 2.74 Lit. in 2008, 1.68 Lit. to 3.6 Lit. in 2009 and 2.02 Lit. to 3.66 Lit. in 2010.

The component analysis for monsoon 2007 revealed that the lung function variable was positively correlated with **RSPM** and **RF** levels, wherein for 2008, it gave correlation between **Max. temp., LL, SO_2, NO_x** and **RSPM;** in 2009 the correlation was found between **CC** and lung function values. In 2010, component analysis gave correlation between **RH, VP** and **CC** with the lung function values. The descriptive analysis for monsoons depicted that the FVC values were varying from 2007 to 2010. The FVC and FEV1 values were relatively low for 2007 as compared to other years. The FVC values ranged from 1.76 Lit. to 2.72 Lit in 2007, 1.88 Lit. to 3.57 Lit. in 2008, 1.86 Lit. to 2.89 Lit. in 2009 and 1.49 Lit. to 3.66 Lit. in 2010.

The component analysis for winters revealed that the lung function variable were positively correlated with **CC** in 2007 and 2008, whereas in 2009 it had shown the positive correlation with **LL, NO_x** and **RSPM**. In 2010, it gave a good correlation between the **Min. Temp**. and **SO_2** with the lung function variability. The descriptive analysis for winters depicted that the FVC values were varying from 2007 to 2010. The FVC and FEV1 values were relatively low for 2007 as compared to other years. The FVC values ranged from 2.18 Lit. to 2.89 Lit in 2007, 1.09 Lit. to 3.6 Lit. in 2008, 1.91 Lit. to 3.16 Lit. in 2009 and 1.58 Lit. to 3.21 Lit. in 2010.

Principal component analysis revealed the fact that all the environmental factors were showing strong correlation with the asthma exacerbations in one or the other season. Hence to understand the significance level between the lung function capacity and the environmental factors, the Bivariate Pearson Correlation was conducted (**Table no. 4.1** to **4.3**).

All the three lung functions expressed the response differently in the summer season. Lung functions **FVC, FEV1** and **PEF** showed a significant positive correlation with **RH** (**2007** – $p < 0.05$ for FVC and PEF; **2008** – $p < 0.05$ for FVC and FEV1 whereas $p < 0.01$ for PEF; **2009** $p < 0.01$ for FVC and PEF whereas $p < 0.05$ for FEV1; **2010** – $p < 0.05$ for FVC and FEV1 whereas $p < 0.01$ for PEF) and **VP** on other hand gave significant positive correlation with **PEF** (**2007, 2009** and **2010** – $p < 0.05$ whereas for **2008** $p < 0.01$). Kljakovic and Salmond (1998); Chavarria (2001) and Carey and Cordon (1986) in their studies have reported that relative humidity is one of the main factor in worsening asthma. Depradine and Lovell (2007) in their studies had revealed there was highest correlation between asthma exacerbations and vapour pressure. Depradine *et al.,* (1995) in their studies found Positive associations with relative humidity and vapour pressure using daily asthmatic and meteorological data. Derrick (1972); Bates (1972); Goldstein (1980) and Tromp (1980) in their studies had established stochastic relations between medical data and weather elements.

Table no. 4.1: Bivariate Pearson Correlation Between Environmental Factors And Lung Function Variables For Summer Season.

Summer	2007			2008			2009			2010		
	FVC	FEV1	PEF	FVC	FEV1	PEF	FVC	FEV1	PEF	FVC	FEV1	PEF
Wind_Speed	0.698	0.687	0.618	.554(*)	.480(*)	.624(**)	.794(**)	.775(**)	.811(**)	0.302	0.268	0.418
Max_Temp	-0.391	-0.477	-0.192	-0.44	-0.36	-.528(*)	-0.313	-0.319	-0.398	-0.346	-0.338	-0.376
Min_Temp	0.523	0.536	0.437	.554(*)	.509(*)	.591(**)	.697(*)	.671(*)	.709(*)	0.236	0.23	0.296
RF	0.753	0.617	.844(*)	.627(**)	.553(*)	.704(**)	0.213	0.197	0.3	.575(**)	.532(*)	.729(**)
RH	.904(*)	0.804	.915(*)	.538(*)	.454(*)	.625(**)	.740(**)	.725(*)	.785(**)	.554(*)	.510(*)	.709(**)
VP	.842(*)	0.769	.830(*)	.540(*)	.456(*)	.626(**)	0.573	0.553	.639(*)	0.381	0.346	.507(*)
CC	0.765	.874(*)	0.439	0.177	0.22	0.131	.716(*)	.700(*)	.661(*)	0.433	0.393	.572(**)
LL	-0.788	-.878(*)	-0.489	-.516(*)	-0.431	-.603(**)	-0.292	-0.275	-0.378	-0.389	-0.344	-.531(*)
SO2	0.056	0.135	-0.065	-0.357	-0.293	-0.431	-0.29	-0.306	-0.324	.497(*)	.452(*)	.618(**)
NOx	0.498	0.25	0.844(*)	-.495(*)	-0.411	-.584(**)	-0.404	-0.414	-0.361	0.335	0.292	0.43
RSPM	-0.261	-0.144	-0.394	-0.429	-0.426	-0.423	.677(*)	.655(*)	.722(*)	.601(**)	.552(*)	.763(**)

** Correlation is significant at the 0.01 level indicating highly significant.

* Correlation is significant at the 0.05 level indicating moderately significant.

Table no. 4.2: Bivariate Pearson Correlation Between Environmental Factors And Lung Function Variables For Monsoon Season.

Monsoon	2007			2008			2009			2010		
	FVC	FEV1	PEF	FVC	FEV1	PEF	FVC	FEV1	PEF	FVC	FEV1	PEF
Wind Speed	0.939	0.939	0.939	-.967(*)	-.970(*)	-0.93	0.378	0.447	0.061	-0.639	-0.632	-0.642
Max Temp	-0.594	-0.594	-0.594	0.894	0.867	0.842	0.595	0.654	0.413	-0.288	-0.249	-0.315
Min_Temp	0.587	0.587	0.587	-.983(*)	.991(**)	-.966(*)	0.475	0.522	0.089	-0.587	-0.581	-0.589
RF	0.617	0.617	0.617	-0.892	-0.875	-0.825	-0.459	-0.482	-0.549	-0.789	-0.828	-0.757
RH	0.675	0.675	0.675	-0.947	-0.925	-0.934	-0.132	-0.136	-0.371	-0.377	-0.423	-0.341
VP	0.646	0.646	0.646	-0.946	-0.923	-0.935	0.123	0.16	-0.244	-0.544	-0.58	-0.515
CC	0.723	0.723	0.723	-0.826	-0.857	-0.805	0.678	0.715	0.611	-0.624	-0.67	-0.588
LL	-0.655	-0.655	-0.655	0.948	0.925	0.93	-0.154	-0.123	-0.014	0.578	0.626	0.541
SO2	0.398	0.398	0.398	0.699	0.655	0.633	-0.492	-0.458	-0.667	0.578	0.635	0.534
NOx	0.025	0.025	0.025	.987(*)	.974(*)	.972(*)	-0.354	-0.327	-0.601	0.657	0.708	0.616
RSPM	0.661	0.661	0.661	.970(*)	.974(*)	0.935	-0.222	-0.172	-0.504	0.392	0.438	0.356

** Correlation is significant at the 0.01 level indicating highly significant.

* Correlation is significant at the 0.05 level indicating moderately significant.

Table no. 4.3: Bivariate Pearson Correlation Between Environmental Factors And Lung Function Variables For Winter Season

Winter	2007			2008			2009			2010		
	FVC	FEV1	PEF	FVC	FEV1	PEF	FVC	FEV1	PEF	FVC	FEV1	PEF
Wind Speed	-0.26	-0.256	-0.268	-0.016	0.012	-0.191	-0.176	-0.17	-0.197	-0.044	-0.029	-0.044
Max Temp	0.365	0.366	0.362	0.069	0.062	.441(*)	-0.361	-0.337	-0.373	-0.034	-0.019	-0.013
Min Temp	0.524	0.52	0.53	0.381	0.372	0.125	-0.306	-0.262	-0.325	0.004	-0.01	0.051
RF	0.53	0.53	0.531	0.103	0.121	-0.051	-0.354	-0.319	-0.359	-0.011	-0.009	0.023
RH	-0.127	-0.124	-0.133	-0.252	-0.231	-.441(*)	-0.286	-0.247	-0.313	-0.026	-0.003	-0.021
VP	.849(**	.850(**)	.847(**)	0.326	0.327	0.03	-0.353	-0.318	-0.358	-0.015	0.004	-0.005
CC	-0.59	-0.587	-0.593	-0.028	-0.005	-.558(**)	-0.304	-0.262	-0.317	-0.017	0.006	-0.014
LL	0.363	0.359	0.371	-0.345	-0.347	0.046	0.274	0.23	0.299	0.027	0.013	0.005
SO2	0.612	0.612	0.613	-0.329	-0.314	-0.306	0.248	0.222	0.276	-0.018	0.011	-0.029
NOx	0.607	0.607	0.607	-0.353	-0.348	-0.12	0.256	0.211	0.277	-0.007	-0.022	-0.011
RSPM	.812(**	.811(**)	.814(**)	-0.135	-0.132	-0.341	0.296	0.257	0.323	-0.012	-0.005	0.015

** Correlation is significant at the 0.01 level indicating highly significant.

* Correlation is significant at the 0.05 level indicating moderately significant.

Monsoon and winter were not showing strong correlation compared to summer. However, in 2008, the environmental factors mainly **wind speed** ($p < 0.05$ for FVC and FEV1) and **minimum temperature** ($p < 0.05$ for FVC and PEF) was showing negative significant correlation. Whereas **NOx** ($p < 0.05$ for all the lung functions) and **RSPM** ($p < 0.05$ for FVC and FEV1) was showing positive significant correlation with the asthma exacerbations. Winter 2009 and 2010 did not show any significant correlation of asthma exacerbations with any of the environmental factors. In 2007, **VP** and **RSPM** ($p < 0.01$ for all three lung functions) showed a highly significant correlation with the asthma exacerbations. In winter 2008, **maximum temperature** ($p < 0.05$ for PEF) was showing positive correlation and on other hand **RH** ($p < 0.05$ for PEF) and **CC** ($p < 0.01$ for PEF) were showing negative correlation significance with the asthma exacerbations.

From the Pearson correlation analysis it can be summarised that summer exacerbations in asthma patients were purely due to the environmental factors because all the factors had a participatory role. Paramesh (2002) in his reviews have suggested that Seasonal variation often acts as trigger particularly in summer. In addition, various epidemiological studies have also revealed that seasonal exposure to air pollution shows an increased number of hospital admissions, emergency care visits, increased asthmatic medicine use and hence leading to asthma exacerbations. (Cody *et al.*, 1992; Weisel *et al.*, 1995; Oryszczyn and Annesi, 1995; Tenias *et al.*, 2002; Stieb *et al.*, 1996; Fauroux *et al.*, 2000 and Garcia-Marcos *et al.*, 2007).

The interrelationship of the environmental factors in winter and monsoon were not as significant as seen in summer season. However, the percentage of asthmatics was comparatively higher, pointing to the fact that the higher percentage is probably due to the mix occurrence of respiratory illness including rhinitis and COPD. Tombacz *et al.*, (2007) in their studies on relation of meteorological elements, biological and chemical air pollutants to respiratory diseases in the winter months there is no relation between the meteorological variables and the number of patients. Janson, (2001) in synoptic evaluation of asthma hospital admissions have reported strong inter-seasonal differential response to weather and air pollution by asthmatics. Respiratory illness are more common in the winter months, when respiratory viral infections are more prevalent in the community and lung function has been shown to fall significantly with reduction in outdoor temperatures (Donaldson, *et al.*, 1999). Waris (1991); Eccles (2002); Quint *et al.*, (2011) in their studies have also got the similar yearly seasonal changes in respiratory illness exacerbation. Our observations are in parallel with the earlier studies wherein the maximum asthma exacerbations were observed in winters (42%) followed by monsoon (33%). However the summer asthma exacerbations were showing positive significant participation of all environmental factors. Hence, 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. Pearson correlation analysis was then carried out to find the significance level of the affected age groups with the environmental factors. (**Table no. 4.4.**)

Age wise participation of environmental factors for asthma exacerbations revealed that **wind speed, minimum temperature** and **RSPM** were the major triggers for the age group 42. Whereas for the age group of 43, it was **wind speed, minimum temperature, RH, VP** as well as **LL** was responsible for asthma exacerbations. For age group 45, maximum number of environmental factors were found to be acting as triggers (i.e **wind speed, minimum temperature, RH, VP, LL** and **RF**). For the age group of 46 years, it was found that **CC** and **RSPM** was responsible for exacerbations whereas for age group of 48 years, **wind speed, minimum temperature, RH, VP** and **RF** were responsible for asthma exacerbations except for LL. From the observation, one can summarise that of all the triggers it is the wind speed, minimum temperature and RSPM which are main participants for asthma exacerbations. Hales *et al.,* (1998b) in their studies have reported the changes in the prevalence of asthma to climatic variation with particular reference to temperature. Cobern *et al.,* (2005) has explained the predominant effect of temperature whereby lung function decreases with temperature, concluding that people are likely to suffer with asthma more in the summer months.

There is evidence that asthma severity is related to seasonal and meteorological factors, and there has been considerable debate about the possible role of various environmental factors in explaining temporal and geographical patterns in asthma prevalence (Martinez, 1994; Seaton *et al.,* 1994; Devalia *et al.,* 1994; Newman, 1995; Strachan, 1995; Burr, 1995 and Balfe *et al.,* 1996). It was therefore thought reasonable to run wind rose and isopleths so as to see the spatio temporal pattern and see the asthmatic prevalence.

Table no.4.4: Age Specific Bivariate Pearson Correlation Between Environmental Factors And Lung Function Variables For Summer Season

Age /	42			43			45			46			48		
Paramater	FVC_pt	FEV1_Pt	PEF_Pt	FVC_pt	FEV1_Pt	PEF_Pt	FVC_pt	FEV1_Pt	PEF_Pt	FVC_pt	FEV1_Pt	PEF_Pt	FVC_pt	FEV1_Pt	PEF_Pt
Wind_Speed	.621(*)	.656(*)	0.411	-0.297	.659(**)	-0.221	-0.503	.711(**)	-0.008	-0.503	0.278	0.199	.605(*)	0.084	0.383
Max_Temp	0.021	-0.112	-0.2	0.092	-0.315	0.455	0.127	-0.382	-0.189	0.131	0.134	0.28	-0.366	-0.513	-0.05
Min_Temp	.717(*)	.679(*)	0.452	-0.291	.574(*)	-0.115	-0.397	.652(*)	-0.137	-0.396	0.189	0.534	.556(*)	-0.253	0.482
RF	0.366	0.424	0.449	-0.203	0.476	-0.459	-0.194	.634(*)	0.03	-0.196	-0.173	0.224	.591(*)	0.154	0.345
RH	0.354	0.451	0.357	-0.234	.583(*)	-0.397	-0.366	.634(*)	0.105	-0.364	0.081	-0.05	.560(*)	0.348	0.248
VP	0.359	0.455	0.359	-0.236	.585(*)	-0.395	-0.368	.636(*)	0.103	-0.366	0.083	-0.045	.562(*)	0.344	0.251
CC	0.13	0.017	0.229	0.058	-0.225	-0.018	0.346	0	-0.215	0.344	-0.489	.697(**)	0.04	-0.551	0.245
LL	-0.315	-0.421	-0.328	0.223	-.568(*)	0.392	0.365	-.608(*)	-0.123	0.363	-0.094	0.109	-0.535	-0.389	-0.214
SO2	0.286	0.168	-0.092	-0.045	-0.003	0.412	-0.15	-0.131	-0.185	-0.142	0.389	0.283	-0.175	-0.466	0.063
NOx	-0.191	-0.311	-0.288	0.179	-0.487	0.433	0.279	-0.535	-0.152	0.278	-0.003	0.178	-0.483	-0.448	-0.155
RSPM	-.656(*)	-0.56	-0.415	0.209	-0.341	0.007	0.196	-0.467	0.224	0.19	-0.028	-.733(**)	-0.396	0.501	-0.47

** Correlation is significant at the 0.01 level indicating highly significant.

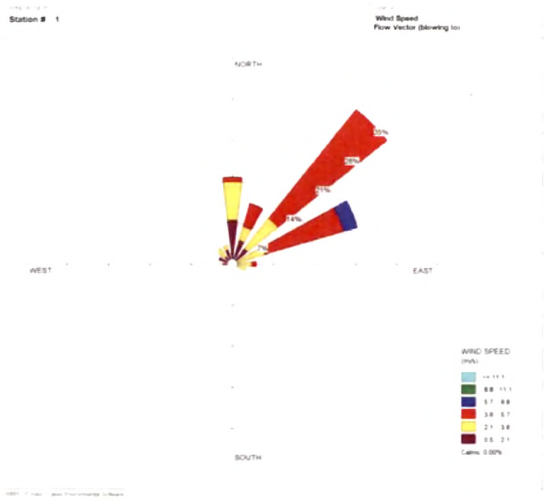
* Correlation is significant at the 0.05 level indicating moderately significant.

B. Spatio Temporal Distribution Of Asthma Patients In Vadodara City:

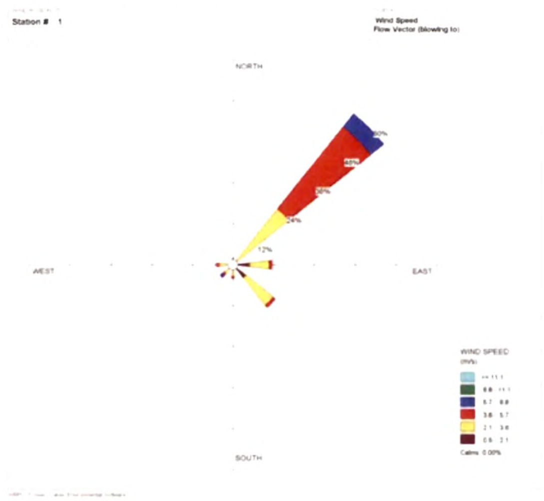
4.3.1 Summer Observations:

Wind Rose Diagrams:

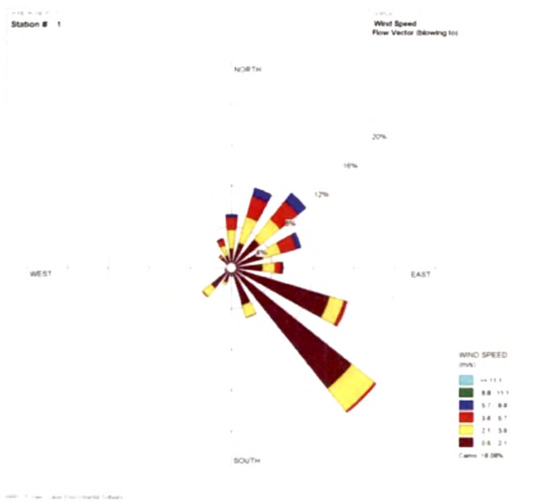
Fig. no. 4.2: Representing Wind Rose For Summer Season 2007 - 2010:



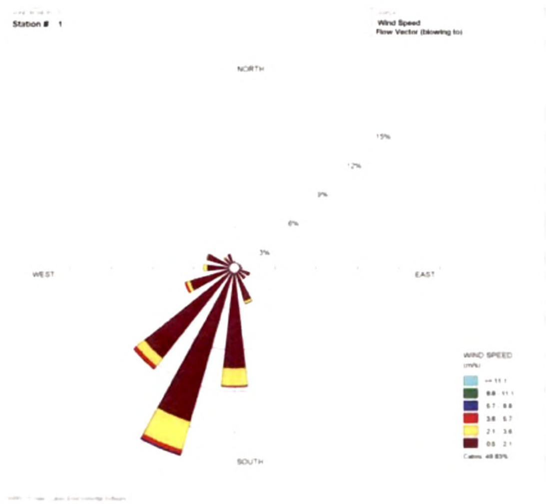
(a) 2007



(b) 2008



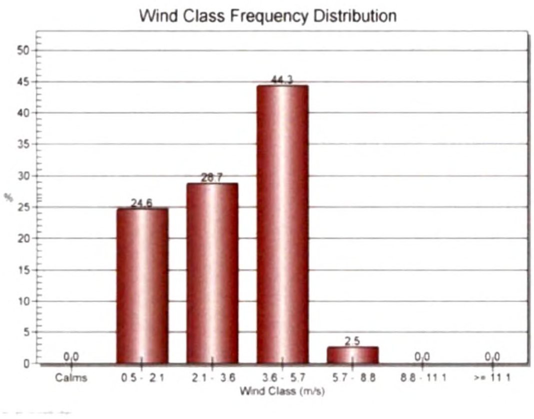
(c) 2009



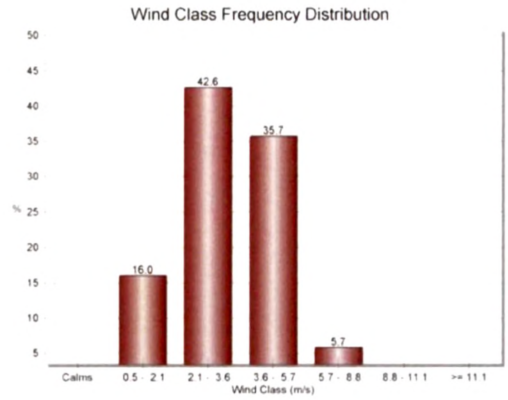
(d) 2010

The wind was predominantly blowing towards the North-East direction until 2008 however in 2009 it moved towards the SE direction followed by SW in 2010 (**Fig. no. 4.2**).

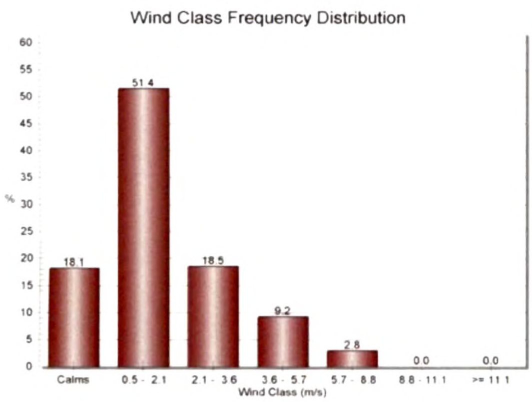
Fig. no. 4.3: Wind Class Frequency Distribution For Summer 2007 – 2010.



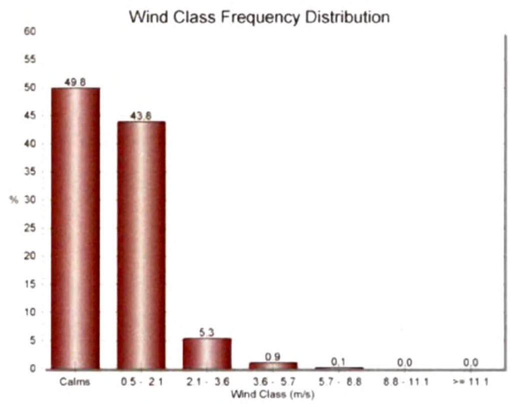
(a) 2007



(b) 2008



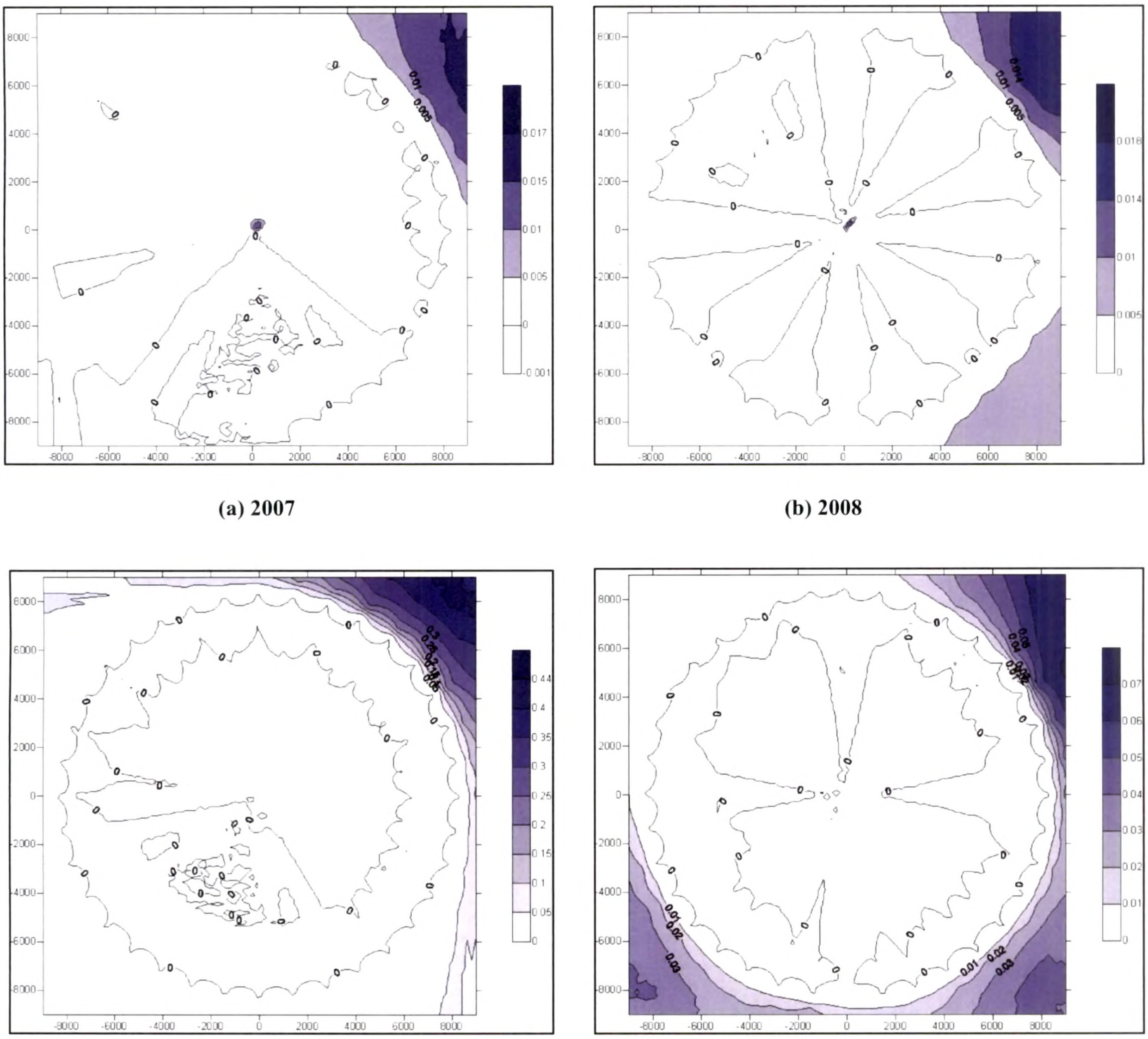
(c) 2009



(d) 2010

The wind class frequency distribution (**Fig. no. 4.3**) clearly indicates that the wind speed was reducing yearly. In 2007 the maximum wind speed being 3.6 to 5.7 m/s, reduced to 2.1 to 3.6 m/s in 2008, followed by 0.5 to 2.1 in 2009 and calm winds in 2010.

Fig. no. 4.4: Isopleth For SO2 Concentration In Summer 2007 – 2010.



(a) 2007

(b) 2008

(c) 2009

(d) 2010

Table no. 4.5: Highest GLC of SO2 in Summer 2007 – 2010.

Highest Values	SO_2 – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.02846	216.51	125
2	0.02669	191.51	160.7
3	0.01618	160.7	191.51
4	0.01383	234.92	85.51
5	0.01125	7.79	4.5
6	0.01076	125	216.51
7	0.01025	6.89	5.79
8	0.01009	85.51	234.92
9	0.00991	8.46	3.08
10	0.00906	43.41	246.2

a.) 2007

Highest Values	SO_2 – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.044	160.7	191.51
2	0.03892	191.51	160.7
3	0.01352	321.39	383.02
4	0.01234	383.02	321.39
5	0.01223	6.89	5.79
6	0.0116	7.79	4.5
7	0.00993	191.51	-160.7
8	0.00969	160.7	-191.51
9	0.00966	250	0
10	0.00936	5.79	6.89

b.) 2008

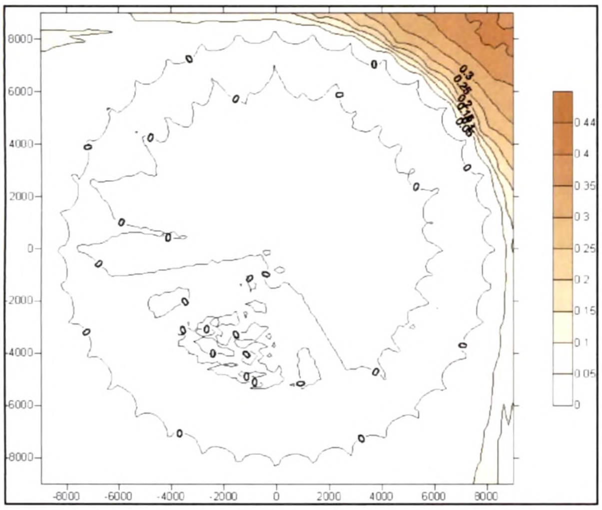
Highest Values	SO_2 – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.24523	4.5	7.79
2	0.22282	7.79	4.5
3	0.2119	5.79	6.89
4	0.20445	6.89	5.79
5	0.19493	3.08	8.46
6	0.166	8.46	3.08
7	0.16527	1.56	8.86
8	0.1349	8.86	1.56
9	0.11641	9	0
10	0.10243	0	9

c.) 2009

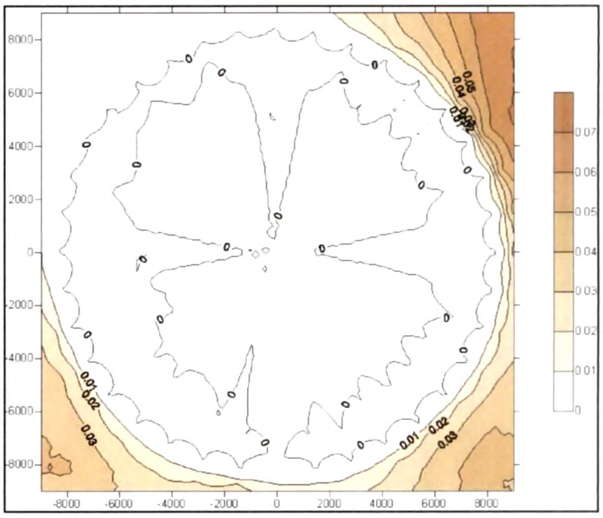
Highest Values	SO_2 – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05337	7.79	4.5
2	0.04732	8.46	3.08
3	0.04028	8.86	1.56
4	0.03863	6.89	5.79
5	0.03564	0	-250
6	0.03561	9	0
7	0.02629	-1.56	-8.86
8	0.02573	8.86	-1.56
9	0.02568	-7.79	-4.5
10	0.02566	5.79	6.89

d.) 2010

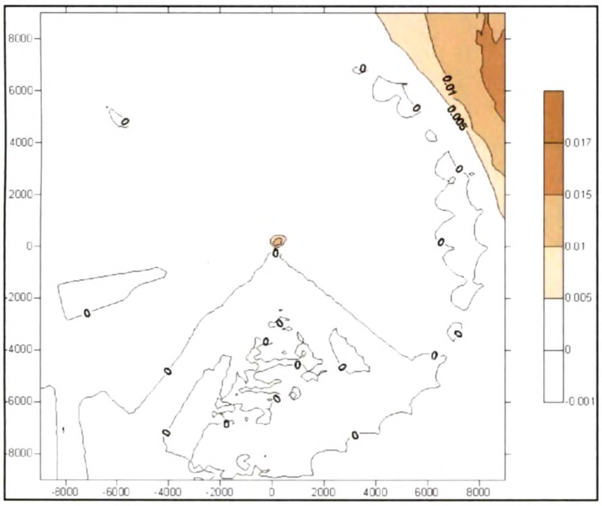
Fig. no. 4.5: Isopleth For NOx Concentration In Summer 2007 – 2010.



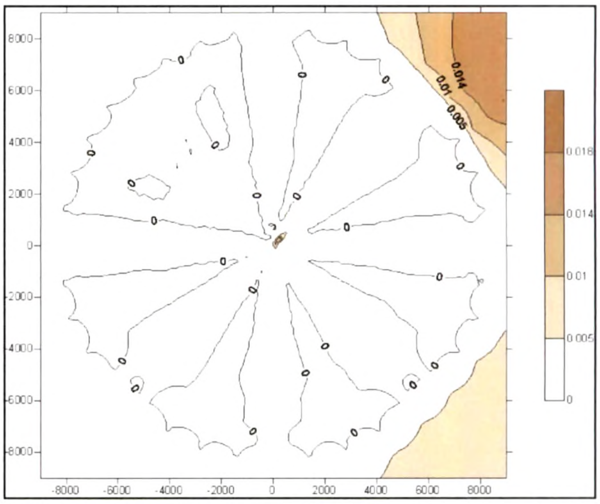
(a) 2007



(b) 2008



(c) 2009



(d) 2010

Table no. 4.6: Highest GLC of NOx in Summer 2007 - 2010

Highest Values	NO_x – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.02846	216.51	125
2	0.02669	191.51	160.7
3	0.01618	160.7	191.51
4	0.01383	234.92	85.51
5	0.01125	7.79	4.5
6	0.01076	125	216.51
7	0.01025	6.89	5.79
8	0.01009	85.51	234.92
9	0.00991	8.46	3.08
10	0.00906	43.41	246.2

a.) 2007

Highest Values	NO_x – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.044	160.7	191.51
2	0.03892	191.51	160.7
3	0.01352	321.39	383.02
4	0.01234	383.02	321.39
5	0.01223	6.89	5.79
6	0.0116	7.79	4.5
7	0.00993	191.51	-160.7
8	0.00969	160.7	-191.51
9	0.00966	250	0
10	0.00936	5.79	6.89

b.) 2008

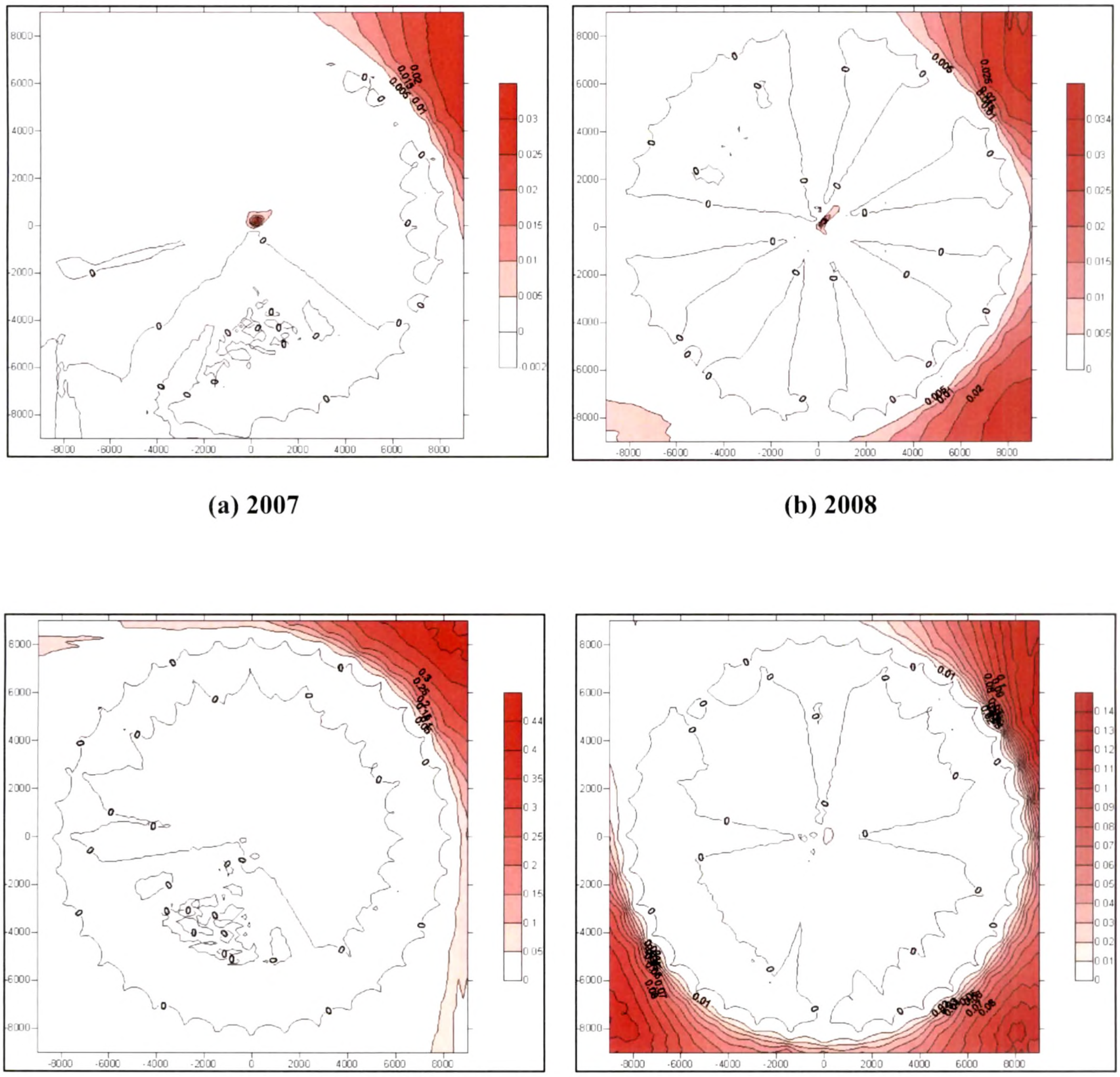
Highest Values	NO_x – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.24523	4.5	7.79
2	0.22282	7.79	4.5
3	0.2119	5.79	6.89
4	0.20445	6.89	5.79
5	0.19493	3.08	8.46
6	0.166	8.46	3.08
7	0.16527	1.56	8.86
8	0.1349	8.86	1.56
9	0.11641	9	0
10	0.10243	0	9

c.) 2009

Highest Values	NO_x – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05337	7.79	4.5
2	0.04732	8.46	3.08
3	0.04028	8.86	1.56
4	0.03863	6.89	5.79
5	0.03564	0	-250
6	0.03561	9	0
7	0.02629	-1.56	-8.86
8	0.02573	8.86	-1.56
9	0.02568	-7.79	-4.5
10	0.02566	5.79	6.89

d.) 2010

Fig. no. 4.6: Isopleth For RSPM Concentration In Summer 2007 – 2010.



(a) 2007 (b) 2008

(c) 2009 (d) 2010

Table no. 4.7: Highest GLC of RSPM in Summer 2007 - 2010

Highest Values	RSPM – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05618	216.51	125
2	0.05362	191.51	160.7
3	0.03283	160.7	191.51
4	0.02704	234.92	85.51
5	0.02166	125	216.51
6	0.02058	7.79	4.5
7	0.02019	85.51	234.92
8	0.01897	8.46	3.08
9	0.01823	43.41	246.2
10	0.01815	6.89	5.79

(a) 2007

Highest Values	RSPM – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0851	160.7	191.51
2	0.067	191.51	160.7
3	0.02582	321.39	383.02
4	0.02297	7.79	4.5
5	0.02277	6.89	5.79
6	0.02173	383.02	321.39
7	0.01791	191.51	-160.7
8	0.01788	160.7	-191.51
9	0.01744	250	0
10	0.01683	6.89	-5.79

(b) 2008

Highest Values	RSPM – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.24523	4.5	7.79
2	0.22282	7.79	4.5
3	0.2119	5.79	6.89
4	0.20445	6.89	5.79
5	0.19493	3.08	8.46
6	0.166	8.46	3.08
7	0.16527	1.56	8.86
8	0.1349	8.86	1.56
9	0.11641	9	0
10	0.10243	0	9

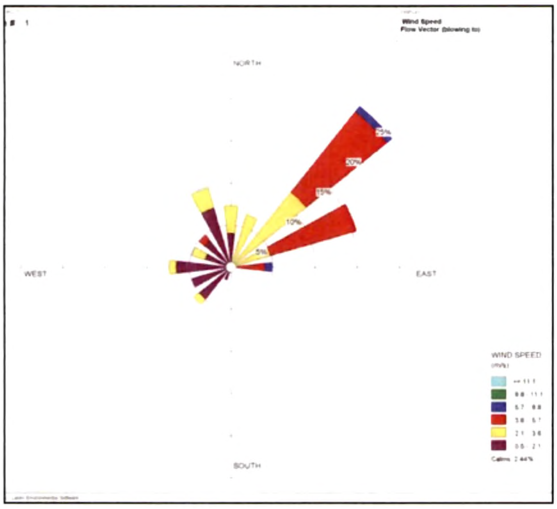
(c) 2009

Highest Values	RSPM – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.09905	7.79	4.5
2	0.09647	8.46	3.08
3	0.08929	8.86	1.56
4	0.07524	-7.79	-4.5
5	0.07426	6.89	5.79
6	0.07072	9	0
7	0.0703	0	-250
8	0.07016	-8.46	-3.08
9	0.06486	-6.89	-5.79
10	0.05948	5.79	-6.89

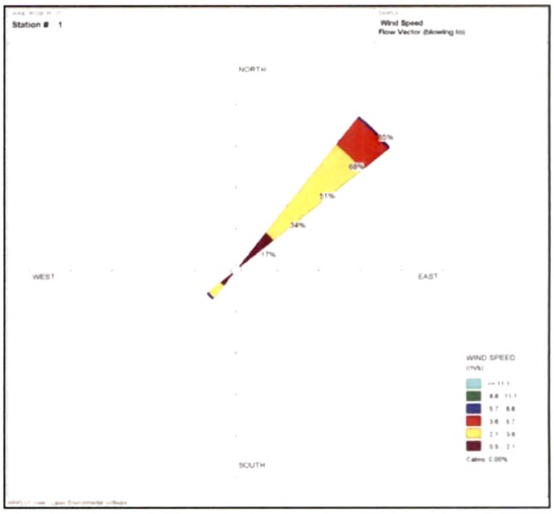
(d) 2010

4.3.2. Monsoon observations:

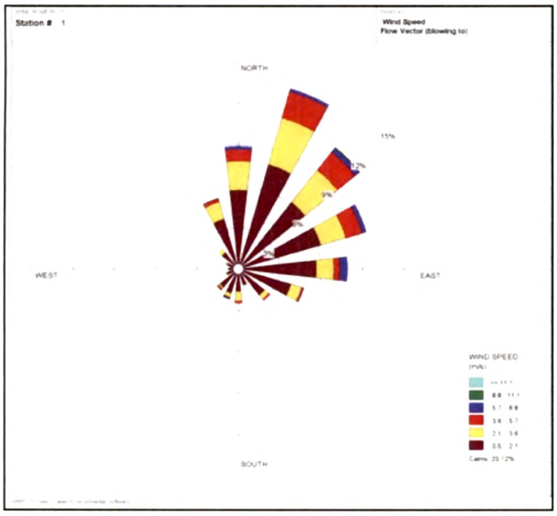
Fig. no. 4.7: Representing Wind Rose For Monsoon Season 2007 – 2010.



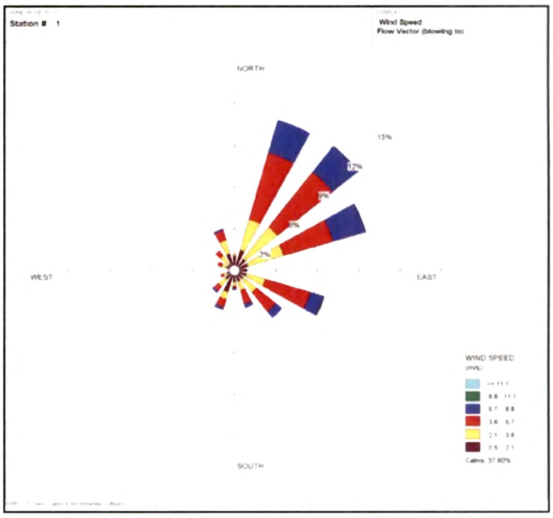
(a) 2007



(b) 2008



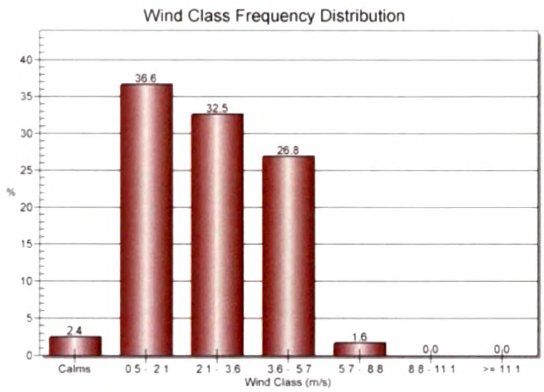
(c) 2009



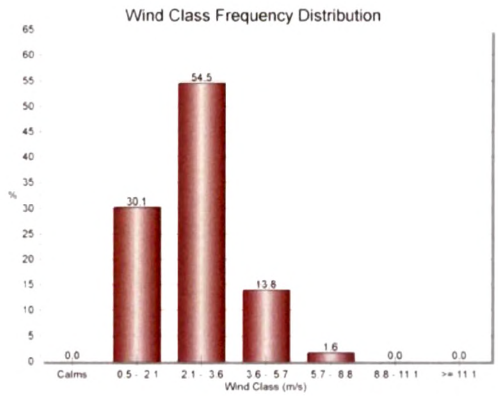
(d) 2010

The wind was predominantly blowing towards the North-East direction as well as the East of North-East direction with high wind speed as compared to 2005. Also, the wind pattern has moved towards the West and North-West direction in 2007 as compared to minor blowing rate as found in 2005 and 2006 monsoon results (**Fig. no. 4.7**).

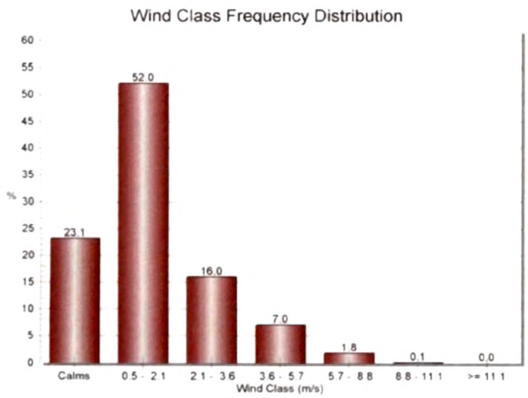
Fig. no. 4.8: Wind Class Frequency Distribution For Monsoon 2007 – 2010.



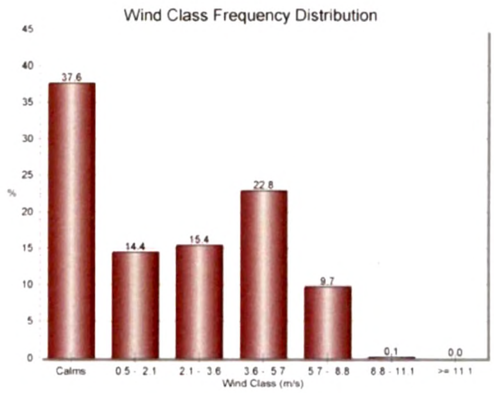
(a) 2007



(b) 2008



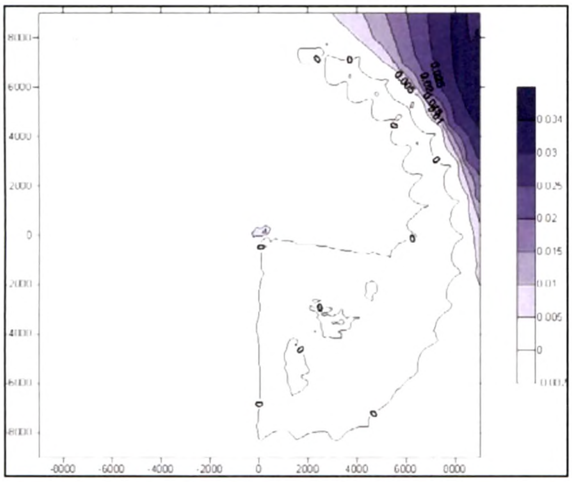
(c) 2009



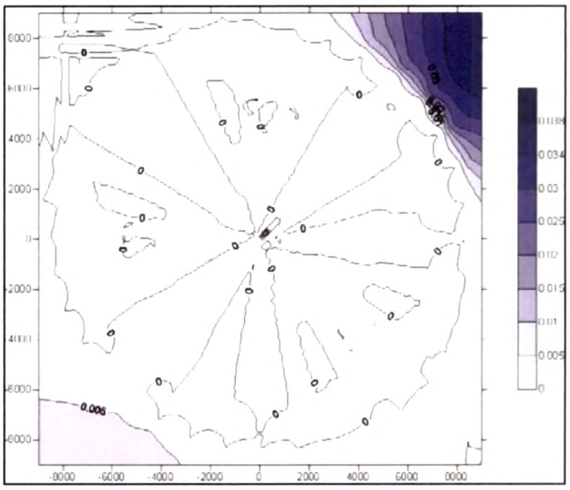
(d) 2010

The maximum wind speed to be 0.5 – 2.1 m/s in 2007 and 2009, 2.1 – 3.5 m/s in 2008 and mostly calm in 2010 (**Fig. no. 4.8**).

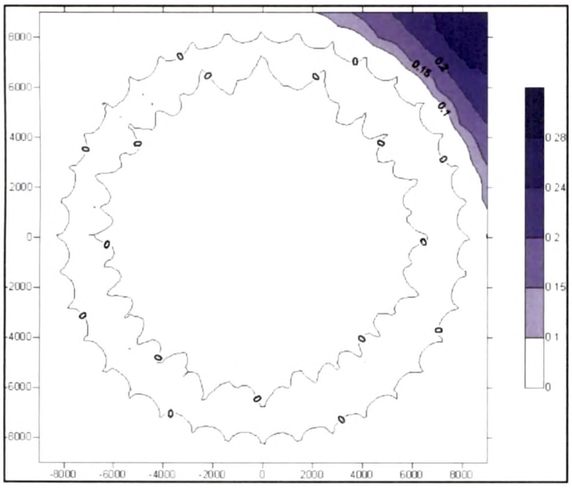
Fig. no. 4.9: Isopleth For SO2 Concentration In Monsoon 2007 - 2010.



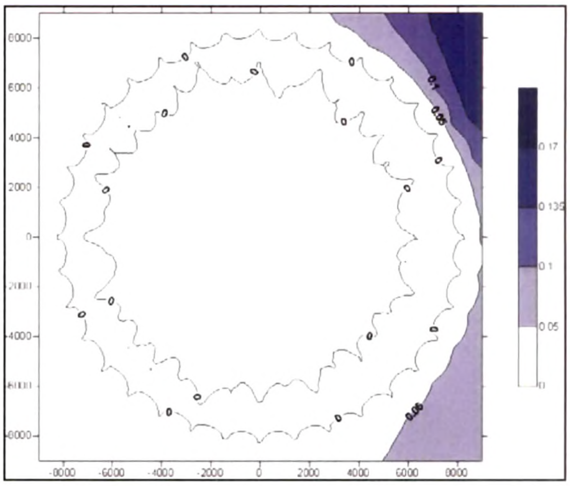
(a) 2007



(b) 2008



(c) 2009



(d) 2010

Table no. 4.8: Highest GLC of SO2 in Monsoon 2007 – 2010

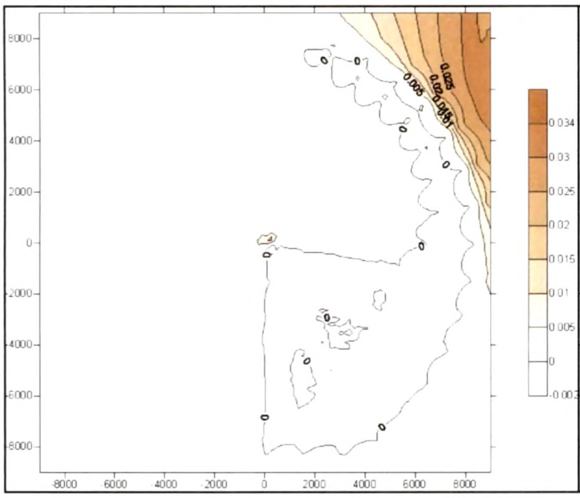
Highest Values	SO_2 – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.02317	7.79	4.5
2	0.02149	8.46	3.08
3	0.02137	191.51	160.7
4	0.0206	6.89	5.79
5	0.0193	216.51	125
6	0.01662	8.86	1.56
7	0.01447	5.79	6.89
8	0.01322	160.7	191.51
9	0.01136	234.92	85.51
10	0.0105	9	0

Highest Values	SO_2 – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05871	160.7	191.51
2	0.05258	191.51	160.7
3	0.02633	6.89	5.79
4	0.0249	7.79	4.5
5	0.02158	5.79	6.89
6	0.02028	321.39	383.02
7	0.01838	383.02	321.39
8	0.0138	8.46	3.08
9	0.01311	4.5	7.79
10	0.01043	125	216.51

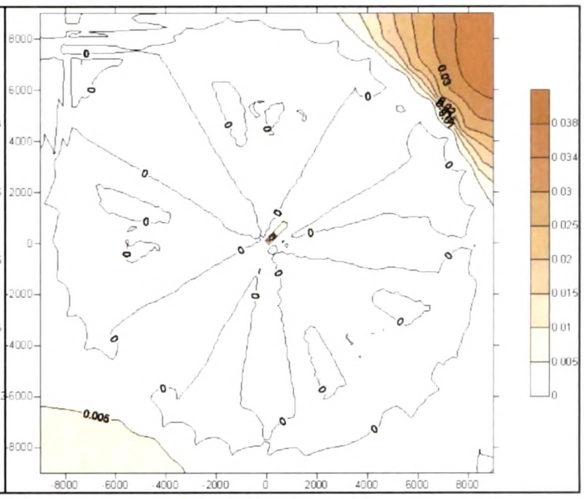
Highest Values	SO_2 – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.10983	7.79	4.5
2	0.09217	8.46	3.08
3	0.08816	6.89	5.79
4	0.07488	8.86	1.56
5	0.07131	5.79	6.89
6	0.07069	4.5	7.79
7	0.06297	9	0
8	0.05402	8.86	-1.56
9	0.0539	8.46	-3.08
10	0.0517	7.79	-4.5

Highest Values	SO_2 – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.14493	7.79	4.5
2	0.13665	6.89	5.79
3	0.13591	4.5	7.79
4	0.1332	5.79	6.89
5	0.12626	8.46	3.08
6	0.11853	8.86	1.56
7	0.10994	3.08	8.46
8	0.10874	9	0
9	0.09267	1.56	8.86
10	0.08453	8.86	1.56

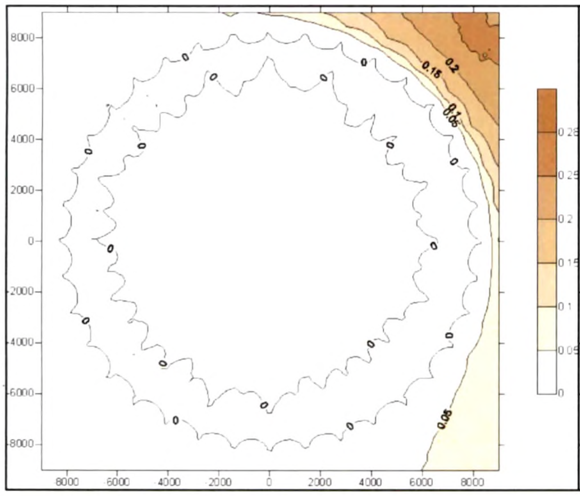
Fig. no. 4.10: Isopleth For NOx Concentration In Monsoon 2007 - 2010.



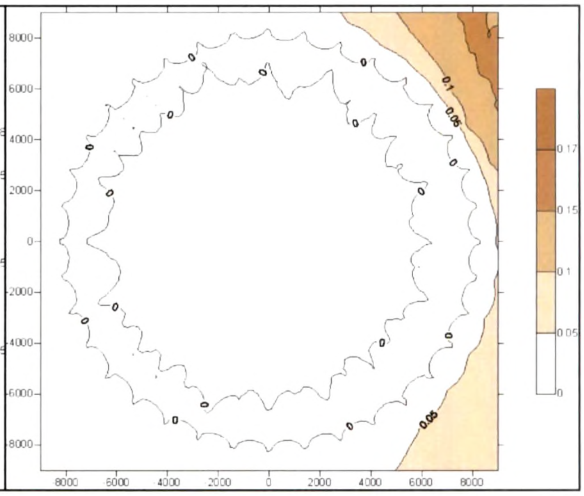
(a) 2007



(b) 2008



(c) 2009



(d) 2010

Table no. 4.9: Highest GLC of NOx in Monsoon 2007 – 2010

Highest Values	NO_x – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.02317	7.79	4.5
2	0.02149	8.46	3.08
3	0.02137	191.51	160.7
4	0.0206	6.89	5.79
5	0.0193	216.51	125
6	0.01662	8.86	1.56
7	0.01447	5.79	6.89
8	0.01322	160.7	191.51
9	0.01136	234.92	85.51
10	0.0105	9	0

a.) 2007

Highest Values	NO_x – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05871	160.7	191.51
2	0.05258	191.51	160.7
3	0.02633	6.89	5.79
4	0.0249	7.79	4.5
5	0.02158	5.79	6.89
6	0.02028	321.39	383.02
7	0.01838	383.02	321.39
8	0.0138	8.46	3.08
9	0.01311	4.5	7.79
10	0.01043	125	216.51

b.) 2008

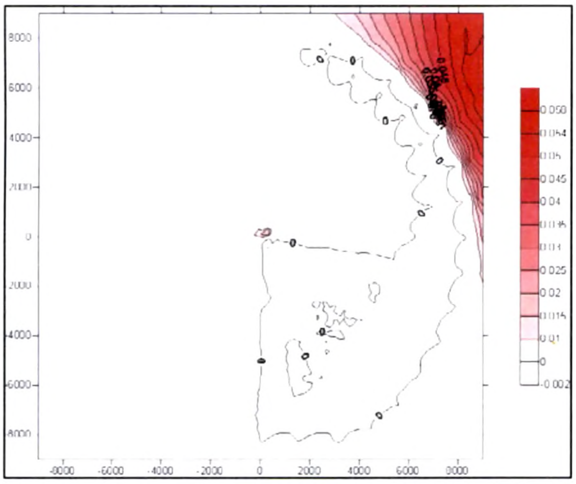
Highest Values	NO_x – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.14493	7.79	4.5
2	0.13665	6.89	5.79
3	0.13591	4.5	7.79
4	0.1332	5.79	6.89
5	0.12626	8.46	3.08
6	0.11853	8.86	1.56
7	0.10994	3.08	8.46
8	0.10874	9	0
9	0.09267	1.56	8.86
10	0.08453	8.86	1.56

c.) 2009

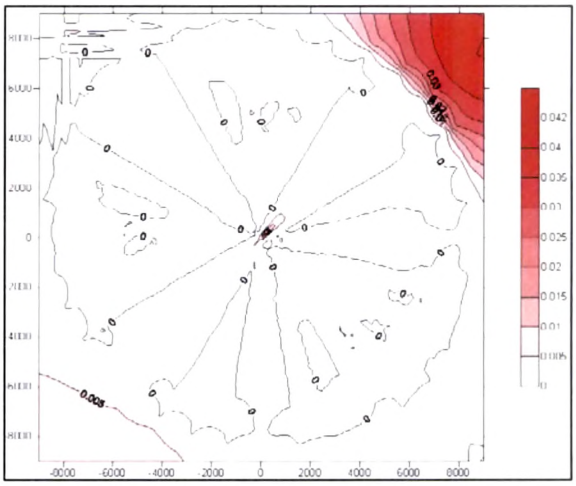
Highest Values	NO_x – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.10983	7.79	4.5
2	0.09217	8.46	3.08
3	0.08816	6.89	5.79
4	0.07488	8.86	1.56
5	0.07131	5.79	6.89
6	0.07069	4.5	7.79
7	0.06297	9	0
8	0.05402	8.86	-1.56
9	0.0539	8.46	-3.08
10	0.0517	7.79	-4.5

d.) 2010

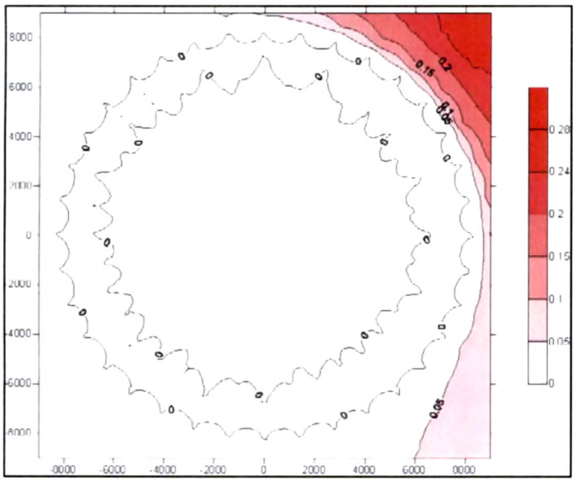
Fig. No. 4.11: Isopleth For RSPM Concentration In Monsoon 2007 - 2010.



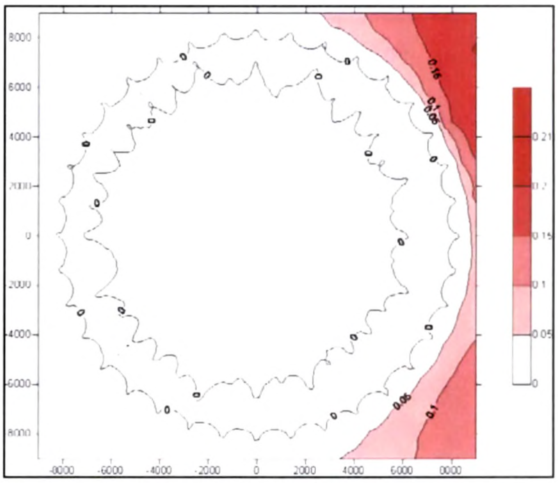
(a) 2007



(b) 2008



(c) 2009



(d) 2010

Table no. 4.10: Highest GLC of RSPM in Monsoon 2007 - 2010

Highest Values	RSPM – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.04018	7.79	4.5
2	0.0393	191.51	160.7
3	0.03765	8.46	3.08
4	0.03549	6.89	5.79
5	0.03466	216.51	125
6	0.02938	8.86	1.56
7	0.0249	5.79	6.89
8	0.02466	160.7	191.51
9	0.02037	234.92	85.51
10	0.01899	9	0

a.) 2007

Highest Values	RSPM – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0824	160.7	191.51
2	0.06624	191.51	160.7
3	0.02831	321.39	383.02
4	0.02746	6.89	5.79
5	0.02525	7.79	4.5
6	0.02446	5.79	6.89
7	0.02347	383.02	321.39
8	0.0169	4.5	7.79
9	0.01492	125	216.51
10	0.01396	8.46	3.08

b.) 2008

Highest Values	RSPM – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.14493	7.79	4.5
2	0.13665	6.89	5.79
3	0.13591	4.5	7.79
4	0.1332	5.79	6.89
5	0.12626	8.46	3.08
6	0.11853	8.86	1.56
7	0.10994	3.08	8.46
8	0.10874	9	0
9	0.09267	1.56	8.86
10	0.08453	8.86	1.56

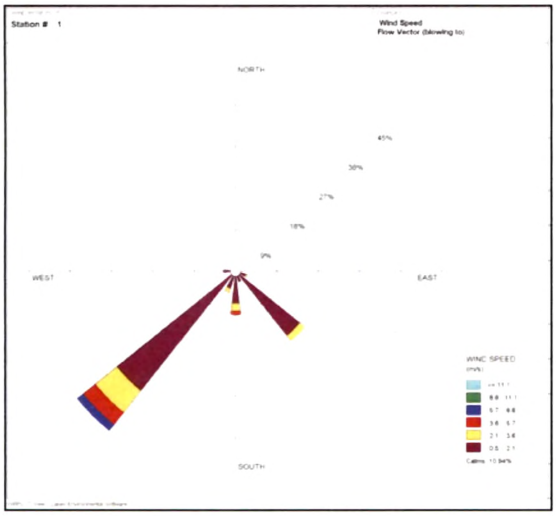
c.) 2009

Highest Values	RSPM – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.13848	7.79	4.5
2	0.12605	8.46	3.08
3	0.10885	6.89	5.79
4	0.10738	8.86	1.56
5	0.08891	9	0
6	0.08506	5.79	6.89
7	0.07963	4.5	7.79
8	0.07413	8.86	-1.56
9	0.07283	7.79	-4.5
10	0.07274	8.46	-3.08

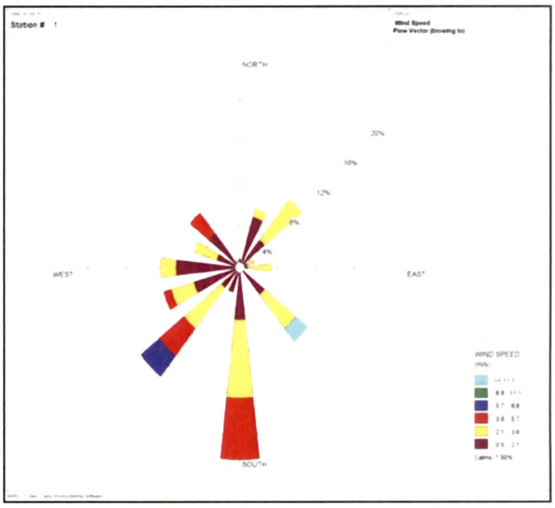
d.) 2010

4.3.3 Winter observations:

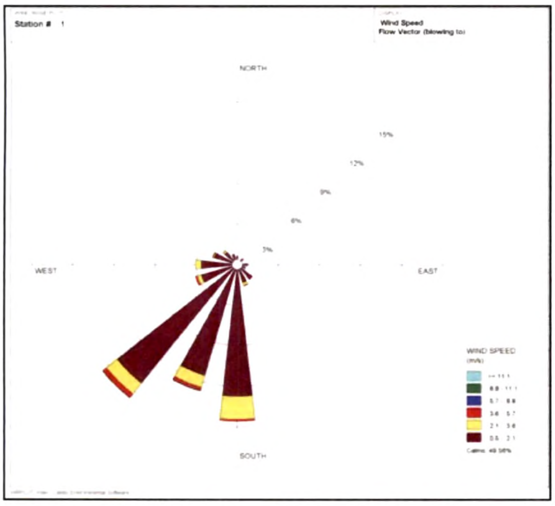
Fig. no. 4.12: Representing Wind Rose For Winter Season 2007 – 2010.



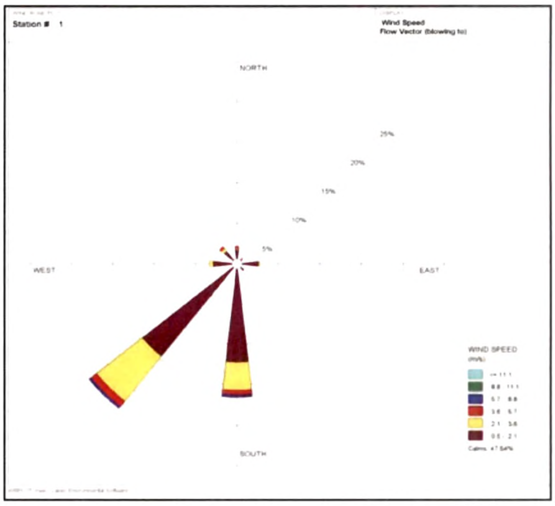
a.) 2007



b.) 2008



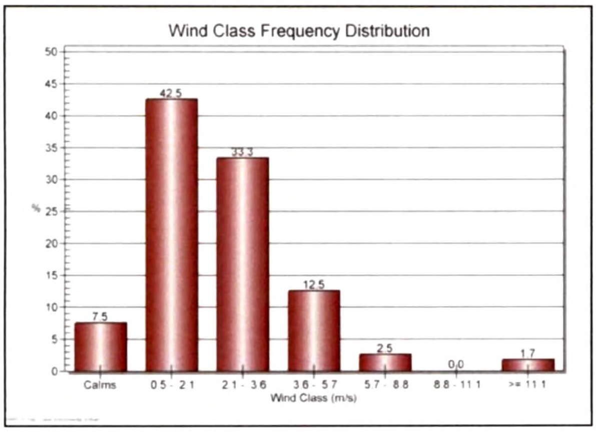
c.) 2009



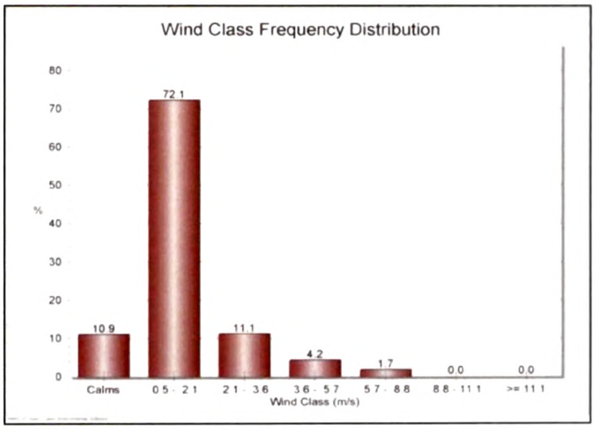
d.) 2010

Unlike 2005 and 2006 wind pattern, the wind rose pattern for 2007 was found to be varying completely. The wind was found to be predominantly blowing in South and South-West direction. Being a mixed type of wind pattern, small proportions of wind were also found in the South East direction (**Fig. no. 4.12**).

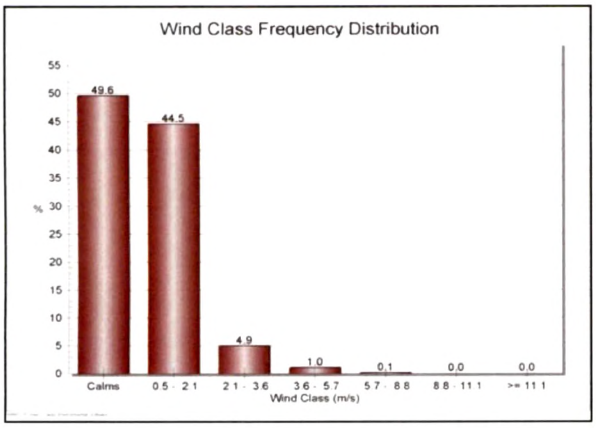
Fig. no. 4.13: Wind Class Frequency Distribution For Winter 2007 - 2010.



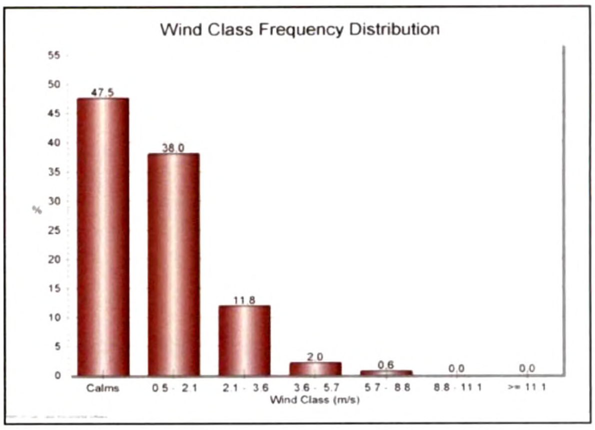
a.) 2007



b.) 2008



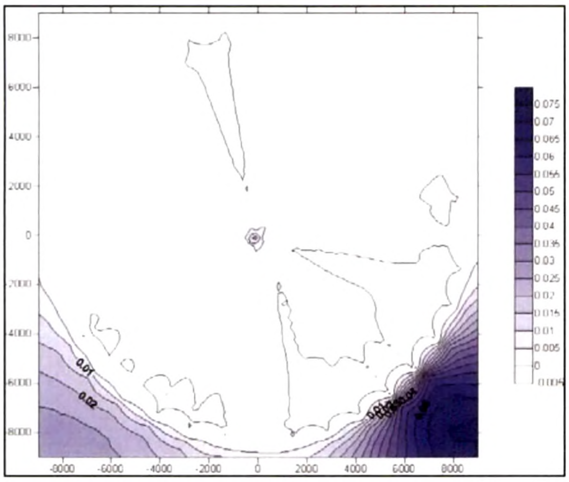
c.) 2009



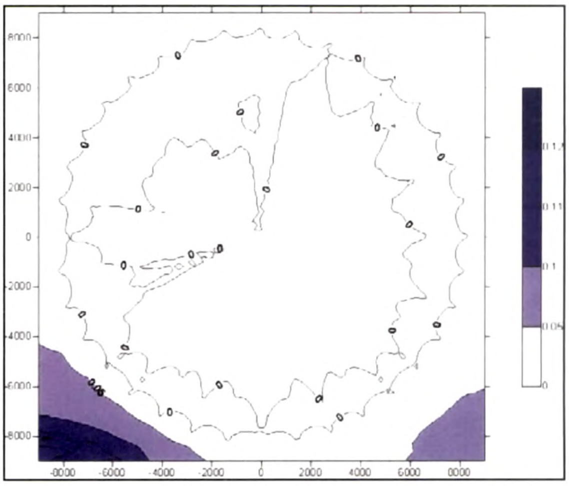
d.) 2010

The wind was predominantly blowing with the maximum wind speed to be 0.5 to 2.1 m/s in 2007 and 2008. The wind was predominantly calm in 2009 and 2010 (**Fig. no. 4.13**).

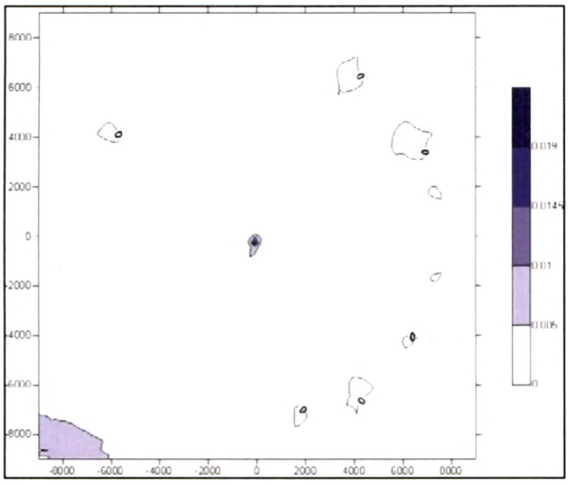
Fig. no. 4.14: Isopleth For SO2 Concentration In Winter 2007 - 2010.



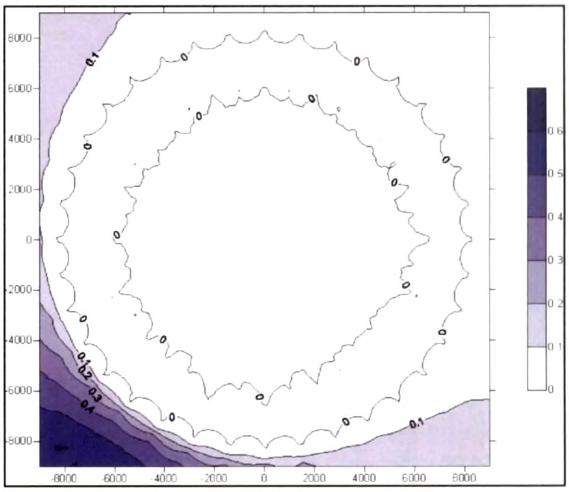
a.) 2007



b.) 2008



c.) 2009



d.) 2010

Table no. 4.11: Highest GLC of SO2 in Winter 2007 – 2010

Highest Values	SO_2 – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05449	6.89	-5.79
2	0.04876	5.79	-6.89
3	0.03636	0	-250
4	0.03201	7.79	-4.5
5	0.02843	-191.51	-160.7
6	0.02464	-160.7	-191.51
7	0.02434	4.5	-7.79
8	0.01765	-234.92	-85.51
9	0.01711	-4.5	-7.79
10	0.01699	-5.79	-6.89

a.) 2007

Highest Values	SO2 – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0817	-4.5	-7.79
2	0.07059	-5.79	-6.89
3	0.06047	-3.08	-8.46
4	0.05603	-6.89	-5.79
5	0.04316	-7.79	-4.5
6	0.04032	-1.56	-8.86
7	0.03481	-191.51	-160.7
8	0.03359	5.79	-6.89
9	0.0329	6.89	-5.79
10	0.03228	-160.7	-191.51

b.) 2008

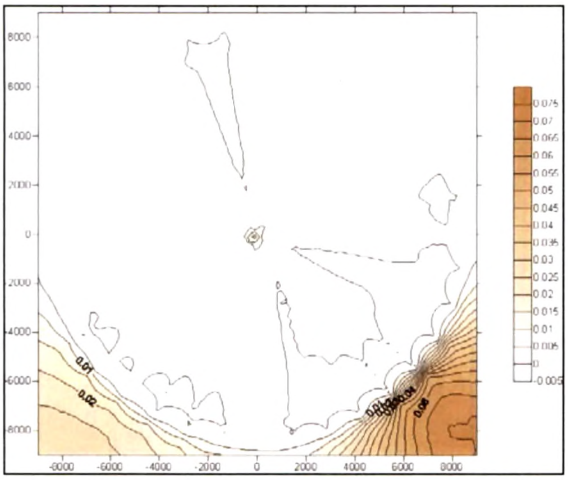
Highest Values	SO2 – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0228	-85.51	-234.92
2	0.01774	0	-250
3	0.01747	-125	-216.51
4	0.01583	-160.7	-191.51
5	0.01533	-43.41	-246.2
6	0.01423	-191.51	-160.7
7	0.01315	-171.01	-469.85
8	0.0107	0	-500
9	0.00946	43.41	-246.2
10	0.00895	-216.51	-125

c.) 2009

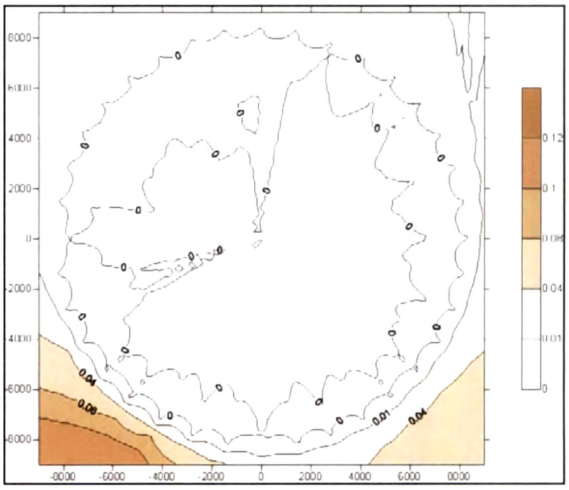
Highest Values	SO2 – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.35951	-4.5	-7.79
2	0.33347	-5.79	-6.89
3	0.31419	-3.08	-8.46
4	0.2977	-1.56	-8.86
5	0.28563	-6.89	-5.79
6	0.25386	0	-9
7	0.25032	-7.79	-4.5
8	0.21235	1.56	-8.86
9	0.20241	-8.46	-3.08
10	0.16367	-8.86	-1.56

d.) 2010.

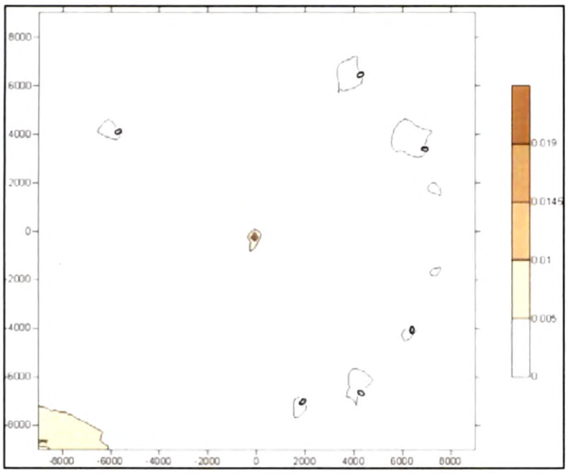
Fig. no. 4.15: Isopleth For NOx Concentration In Winter 2007 - 2010.



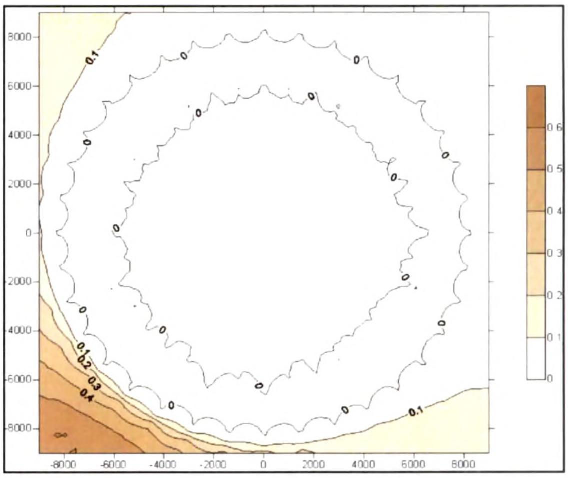
a.) 2007



b.) 2008



c.) 2009



d.) 2010

Table no. 4.12: Highest GLC of NOx in Winter 2007 – 2010

Highest Values	NO_x – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05449	6.89	-5.79
2	0.04876	5.79	-6.89
3	0.03636	0	-250
4	0.03201	7.79	-4.5
5	0.02843	-191.51	-160.7
6	0.02464	-160.7	-191.51
7	0.02434	4.5	-7.79
8	0.01765	-234.92	-85.51
9	0.01711	-4.5	-7.79
10	0.01699	-5.79	-6.89

a.) 2007

Highest Values	NO_x – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0817	-4.5	-7.79
2	0.07059	-5.79	-6.89
3	0.06047	-3.08	-8.46
4	0.05603	-6.89	-5.79
5	0.04316	-7.79	-4.5
6	0.04032	-1.56	-8.86
7	0.03481	-191.51	-160.7
8	0.03359	5.79	-6.89
9	0.0329	6.89	-5.79
10	0.03228	-160.7	-191.51

b.) 2008

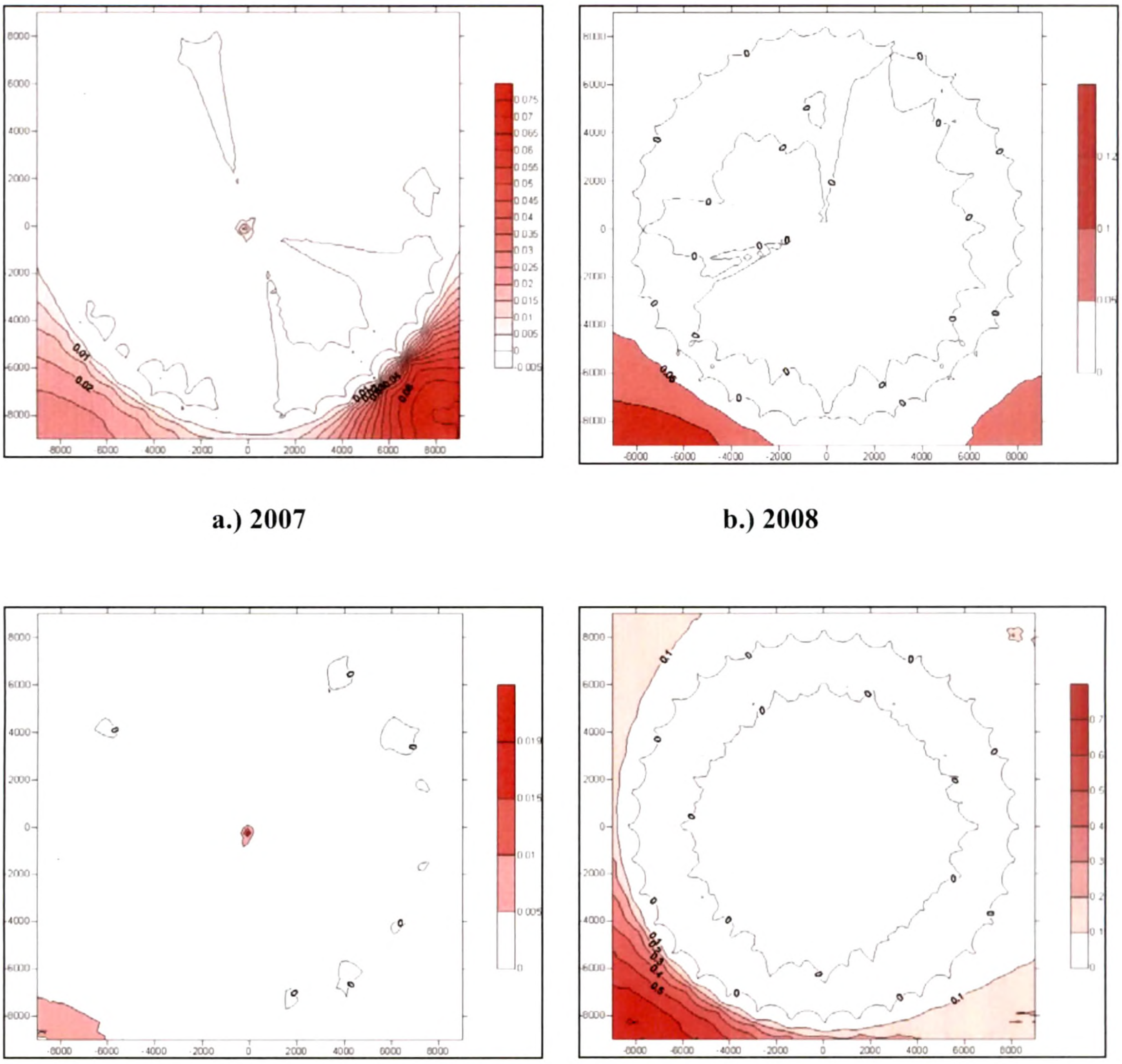
Highest Values	NO_x – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0228	-85.51	-234.92
2	0.01774	0	-250
3	0.01747	-125	-216.51
4	0.01583	-160.7	-191.51
5	0.01533	-43.41	-246.2
6	0.01423	-191.51	-160.7
7	0.01315	-171.01	-469.85
8	0.0107	0	-500
9	0.00946	43.41	-246.2
10	0.00895	-216.51	-125

c.) 2009

Highest Values	NO_x – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.35951	-4.5	-7.79
2	0.33347	-5.79	-6.89
3	0.31419	-3.08	-8.46
4	0.2977	-1.56	-8.86
5	0.28563	-6.89	-5.79
6	0.25386	0	-9
7	0.25032	-7.79	-4.5
8	0.21235	1.56	-8.86
9	0.20241	-8.46	-3.08
10	0.16367	-8.86	-1.56

d.) 2010.

Fig. no. 4.15: Isopleth For NOx Concentration In Winter 2007 - 2010.



a.) 2007 b.) 2008

c.) 2009 d.) 2010

Table no. 4.13: Highest GLC of RSPM in Winter 2007 – 2010

Highest Values	RSPM – 2007 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.05449	6.89	-5.79
2	0.04876	5.79	-6.89
3	0.03636	0	-250
4	0.03201	7.79	-4.5
5	0.02843	-191.51	-160.7
6	0.02464	-160.7	-191.51
7	0.02434	4.5	-7.79
8	0.01765	-234.92	-85.51
9	0.01711	-4.5	-7.79
10	0.01699	-5.79	-6.89

a.) 2007

Highest Values	RSPM – 2008 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0817	-4.5	-7.79
2	0.07059	-5.79	-6.89
3	0.06047	-3.08	-8.46
4	0.05603	-6.89	-5.79
5	0.04316	-7.79	-4.5
6	0.04032	-1.56	-8.86
7	0.03481	-191.51	-160.7
8	0.03359	5.79	-6.89
9	0.0329	6.89	-5.79
10	0.03228	-160.7	-191.51

b.) 2008

Highest Values	RSPM – 2009 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.0228	-85.51	-234.92
2	0.01774	0	-250
3	0.01747	-125	-216.51
4	0.01583	-160.7	-191.51
5	0.01533	-43.41	-246.2
6	0.01423	-191.51	-160.7
7	0.01315	-171.01	-469.85
8	0.0107	0	-500
9	0.00946	43.41	-246.2
10	0.00895	-216.51	-125

c.) 2009

Highest Values	RSPM – 2010 Concentration	X Co-ord (mts)	Y Co-ord (mts)
1	0.39942	-4.5	-7.79
2	0.38087	-5.79	-6.89
3	0.34697	-3.08	-8.46
4	0.34	-6.89	-5.79
5	0.3242	-1.56	-8.86
6	0.30975	-7.79	-4.5
7	0.27517	0	-9
8	0.26329	-8.46	-3.08
9	0.22952	1.56	-8.86
10	0.22141	-8.86	-1.56

d.) 2010.

4.4 DISCUSSION

Having established the seasonal age wise recognized environmental triggering factors and altered lung functions, In order to determine the most appropriate meteorological factor and the pollutants acting as a trigger for the sample size, data were acquired and wind roses were developed and analyzed for Vadodara city for the period of four years (2007-2010). Seasonal and annual average dispersion modelling was performed for each of four years. Im *et al.*, (2000); Chng (2004) and Cai *et al.*, (2007) in their studies have also made use of Air Quality Dispersion Modelling/Exposure Assessment for asthma prevalence. With the same line of thought in the present studies wind rose and ISCST3 modelling was performed. To help smooth out any year-to-year meteorological variability, composite four-year average seasonal and annual average concentration values were calculated at each modelled receptor for purposes of identifying long-term (chronic) impacts within the study area. The seasonal and annual concentrations at each receptor for each pollutant modelled therefore represent a four year composite average to facilitate and understand the spatial and temporal variation by evaluating and correlating the concentration predictions with asthma prevalence data. Tables (**Table no. 4.5 to 4.13**) and graphics (**Fig. no. 4.4** to **4.6**, **4.9** to **4.11** and **4.14** to **4.16**) are depicting the dispersion modelling. There was a distinct seasonal variation. The analysis showed that the relation between asthmatics and meteorological parameters was strongest during summer. In summer 2007 the wind rose pattern (**Fig. no. 4.2 a**) showed that the wind was predominantly blowing towards the NE direction with the wind speed (**Fig. no. 4.3**) ranging from 2.1 to 5.7 m/s covering the dispersion in larger area and further more through ISCST3 modelling (**Fig. no. 4.4 a** and **4.5 a**) it was found that the ground level concentration of SO_2 and NO_x was ranging from 0.028 $\mu g/m^3$ to 0.009 $\mu g/m^3$.(**Table no. 4.5 a** and **4.6 a**) The pollution pockets were more concentrated in the central part of the city i.e near the railway station and also towards the NE i.e Harni. When residential addresses of the asthmatics were cross checked it was found that majority of females were residing in and around the pollution pockets. The wind rose pattern in summer 2008 (**Fig. no. 4.2 b**) was different from that observed in summer 2007. However, ISCST3 modelling showed pollution pockets (**Fig. no. 4.4 b** and **4.5 b**) to be more concentrated in NE and SE, with the marginal increase (ranging from 0.044 $\mu g/m^3$ to 0.009 $\mu g/m^3$) in the ground level concentration .(**Table no. 4.5 b** and **4.6 b**) of the pollutant as compared to Summer 2007 however the occurrence of asthma exacerbations among the dedicated age group was found to be against the pollution pockets but in-line with the wind rose pattern. In summer 2009 (**Fig. no. 4.2 c**), the wind was found to be blowing towards the NE and gradually moving towards the SE direction (**Fig. no. 4.4 c** and **4.5 c**) which was in parallel with the occurrence of the asthma exacerbation in the dedicated age group. There was significant increase in the ground level concentration which reached upto 0.245 $\mu g/m^3$ to 0.010 $\mu g/m^3$.(**Table no. 4.5 c** and **4.6 c**). In Summer 2010, it was found that wind pattern (**Fig. no. 4.2 d**) again changed from the SE to the SSW direction (**Fig. no. 4.4 d** and **4.5 d**) coinciding with the asthma exacerbations in the particular age group of 41 to 50 years in females. The dispersion pattern revealed that in Summer 2010 the ground level concentration .(**Table no. 4.5 d** and **4.6 d**) ranged from 0.053 $\mu g/m^3$ to 0.020 $\mu g/m^3$ in NE, SE to SW direction, but the concentration of the pollutant had decreased. Overall the concentration of the air pollutants were quite low compared to the permissible level but this low concentration was also acting as a triggering factor for the reported asthmatics.

In Monsoon 2007 (**Fig. no. 4.7 a**) and 2008 (**Fig. no. 4.7 b**), the wind was predominantly blowing towards the NE direction with the wind speed ranging from 0.5 m/s to 2.1 m/s in 2007 (**Fig. no. 4.8 a**) and 2.1 to 5.7 m/s in 2008 (**Fig. no. 4.8 b**) however through ISCST3 modelling it was found that in 2007, the ground level concentration was ranging from 0.023 $\mu g/m^3$ to 0.010 $\mu g/m^3$ in 2007 (**Table no. 4.8 a** and **4.9 a**) and 0.058 $\mu g/m^3$ to 0.010 $\mu g/m^3$ in 2008 (**Table no. 4.8 b** and **4.9 b**) wherein the pollution pocket was also found in SW region. In Monsoon 2009 (**Fig. no. 4.7 c**), the wind speed (**Fig. no. 4.8 c**) was ranging from 0.5 m/s to 2.1 m/s having the increased pollution level with the ground level concentration reaching upto 0.145 $\mu g/m^3$ to 0.008 $\mu g/m^3$ (**Table no. 4.8 c** and **4.9 c**) in the NE direction. However, in monsoon 2010, the wind was mainly calm with the ground level concentration of SO_2 and NO_x ranged from 0.11 $\mu g/m^3$ to 0.05 $\mu g/m^3$ (**Table no. 4.8 d** and **4.9 d**) in NE and SE direction. The dispersion pattern for RSPM had shown almost the same pattern as that of SO_2 and NO_x wherein the pollution was more concentrated in the NE direction in 2007 and in NE and SW in 2008, with the ground level concentration raging from 0.04 to 0.018 $\mu g/m^3$ (**Table no. 4.10 a**) and increasing to 0.08 to 0.013 $\mu g/m^3$ (**Table no. 4.10 b**) respectively. In 2009 (**Table no. 4.10 c**), the ground level concentration was 0.14 $\mu g/m^3$ to 0.08 $\mu g/m^3$ which decreased to 0.13 $\mu g/m^3$ to 0.07 $\mu g/m^3$ in 2010 (**Table no. 4.10 d**) predominantly towards the NE and SE direction. The alterations in the lung functions were observed in the monsoon season but it was not found coinciding with the identified pollution pockets. Studies by Chhabra *et al.*, (1999); Tsai *et al.*, (2006) and Duffy (1997) have shown the genetic predisposition as one of the factor of prevalence of the disease. In the present studies also the significant response not shown by the selected subjects during monsoon possibly could be due to other factors such as either viral infection or due to hereditary disease (Sibbald *et al.*, 1980).

In Winter 2007, the wind was predominantly blowing (**Fig. no. 4.12 a**) towards the South and SW direction with the wind speed ranging from 0.5 to 2.1 m/s (**Fig. no. 4.13 a**) where the pollution (**Fig. no. 4.14 a** and **4.15 a**) was also more concentrated in the central regions of the city i.e near the railway station and also towards the SE and SW of the city with the ground level concentration (**Table no. 4.11 a** and **4.12 a**) of SO_2 and NO_x ranging from 0.054 $\mu g/m^3$ to 0.016 $\mu g/m^3$. Whereas in winter 2008 (**Fig. no. 4.12 b**), the wind was predominantly blowing towards the SW of the city with the maximum wind speed ranging (**Fig. no. 4.13 b**) from 0.5 to 2.1 m/s. As per the wind pattern, the pollution dispersion (**Fig. no. 4.14 b** and **4.15 b**) was found in SE and SW, with the ground level concentration ranging from 0.081 $\mu g/m^3$ to 0.032 $\mu g/m^3$. (**Table no. 4.11 b** and **4.12 b**) During winter 2009 (**Fig. no. 4.12 c**) and 2010 (**Fig. no. 4.12 d**), wind was predominantly blowing towards the south and SW with the maximum wind speed (**Fig. no. 4.13 c** and **d**) being calm and the ground level concentration of SO_2 and NO_x ranging from 0.028 $\mu g/m^3$ to 0.008 $\mu g/m^3$ in 2009 (**Table no. 4.11 c** and **4.12 c**) and increasing to 0.36 $\mu g/m^3$ to 0.16 $\mu g/m^3$ in winter 2010 (**Table no. 4.11 d** and **4.12 d**). The dispersion pattern of RSPM in 2007 and 2009 was in SE and SW direction, with the ground level concentration raging from 0.054 to 0.016 $\mu g/m^3$ in 2007 (**Table no. 4.13 a**), and 0.023 to 0.008 $\mu g/m^3$ in 2009 (**Table no. 4.13 c**). In 2008 (**Table no. 4.13 b**), the pollution was more concentrated in SE and SW direction 0.08 to 0.032 $\mu g/m^3$ whereas it was in NW, SE and SW in 2010 (**Table no. 4.13 d**) with the ground level concentration ranging from 0.39 to 0.22 $\mu g/m^3$. The pollutant pockets were seen to be more concentrated in the central part of the city i.e in and around railway station. A growing body of literature is emerging which links exposure to traffic related air pollution in asthma; most of the epidemiological studies use traffic as a surrogate for investigating its effects on respiratory health. Traffic exposure at close proximity to the surrounding areas have shown a strong correlation with asthma prevalence among adults (Lindgren *et al.*, 2010; Mckone and Ozkaynak 2009; Briggs 2005 and Setton *et al.*, 2011). During winter season, number of visits for asthmatics were more but the area wise distribution of the patients did not show any correlation with the wind rose pattern and ISCST3 results. In the present study as the aim was to investigate the association of meteorological factors and pollutants and was not specifically for traffic exposure one needs to confirm further for the relative contribution of the traffic related emissions and response to asthma prevalence.

Seasonal differences observed in spatio temporal plots considered in different seasons reflects the different scales of the physical processes underlying the pollutants distribution across space and time (Yu *et al.*, 2009). The altered lung functions and area wise pollution pockets represented by the wind rose patterns and ISCST3 models was found to be parallel with the asthma exacerbations only in summer season, pointing to the fact that the reported asthmatics were more sensitive to these pollutants as well as the meteorological factors were acting as triggers. Our results were in agreement with the observations made McConnell *et al.*, (1999) and Ramadour *et al.*, (2000) who have clearly indicated the prevelance of asthma is dependent on the pollution level concentration and wind pattern in the city. Decreased lung function and increase prevelance of asthma with exposure to SO_2 and NO_x has been reported by Kunzli *et al.*, (1997), McConnell *et al.*, (1999), Hirsch *et al.*, (1999) and Ramadour *et al.*, (2000). Although the effects of pollutants and meteorological factors together are still not well understood, the present study points to a synergistic exacerbation of symptoms due to exposure of multiple factors. Individual pollutant has not been taken into consideration for the present study but synergistic effect of pollutant could be a possible reason for noted prevalence of asthma in selected group.

4.5 CONCLUSION:

In the present study our main aim was to find the correlation between asthma exacerbation with respect to alteration in lung function capacity and environmental triggers. 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. Lung function analysis showed 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, **FVC, FEV1** and **PEF** showed a significant positive correlation with **RH** and **VP** during summer. 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%). Results of seasonal differences observed in spatio temporal plots considered in different seasons reflects the different scales of the physical processes underlying the pollutants distribution across space and time. The frequencies of specific wind directions as well as the wind speeds varied from year to year due to the frequency of weather patterns. 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, suggesting that the monsoon and winter season exacerbations were probably not due to the environmental triggers but they may be due to the respiratory viral illness or genetic predisposition.

Having known that during summer season environmental triggers were showing maximum correlation, individual lung functions also exhibited differential correlation with environment factors with respect to FVC, FEV1 and PEF. PEF is considered as a valuable marker of bronchial asthma as well as an indicator of poor prognosis (Bagg and Hughes, 1980) and hence considering the same, peak flow meters were supplied to the selected patients of the age group 41 – 50 years to record the PEF values and monitor the asthma exacerbations.