RESEARCH ARTICLE

Assessment of asthma-prone environment in Karachi, Pakistan using GIS modeling

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Abstract

Objectives: To determine the association among number of factors influenced by asthma using geographic information system.

Methods: The cross-sectional study was conducted in Landhi and Korangi towns of Karachi from 2011 to 2013, and comprised ecological mapping and multi-criteria evaluation techniques to discover the relationship of local environmental settings with asthma. Additionally, exacerbating environment and the root causes within the local settings were assessed. Data was gathered using an extended version of the questionnaire developed by the International Union against Tuberculosis and Lung Disease. Data was analysed by using ArcGIS 10.

Results: The findings are very alarming as almost 40% (468,930 estimated pop 1998 census) of the study population lived in high asthma-prone environment, having a very high risk of respiratory disorders, including asthma.

Conclusion: The integrated environmental effect in the form of respiratory disorders was appraised, focusing on asthma by using multi-criteria analysis.

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Introduction

Asthma is a serious global health problem as people of all age groups, colours, geographic locations and socioeconomic groups all over the world are affected by this chronic disorder which is sometimes fatal for the patients. The estimated number of patients with asthma has doubled throughout the world during the last two decades.[1] Due to unhygienic living and working environments, the poor, especially industrial workers, are more prone to this disorder than others.[2] The asthma prevalence is increasing in the urban areas of Pakistan. About 10% population of Pakistan's largest city Karachi has chronic asthma.[3,4]

New technological innovations always bring changes in science- and health-related research. Statistical- and computer-based spatial modelling helps in discovering new dimensions of facts.[5] Ecology and aetiology of disease has become much easier to understand with the growth of new technologies.[6-8] Many studies indicate the potential of geographic information system (GIS) and its allied technologies to investigate the relationship between environmental factors and frequency of diseases.[9-11] GIS has become an essentially integral part of community health systems that is used for the representation and analysis of disease data in a map form in many parts of the world.[12-18]

The aetiology of asthma varies considerably from person to person. Typical asthma triggers are outdoor air pollution, indoor allergens, pollens, family history, and behavioural causes, such as cigarettes.[19-26] Researchers have explored the link between outdoor air pollution and asthma in an urban environment.[27-32] and have demonstrated that the exposure to major air pollutants, including ozone, sulphur dioxide, nitrogen dioxide, and suspended particulate matter, is related to high asthma prevalence and the rate of hospitalisation.[33-42]

The causes of asthma are uncertain and localised.[43,44] Though we already know that, there is still more to be learned about what causes and exacerbates the asthma, we know that a number of factors can influence this disease as a lot of studies advocated, including the indoor and outdoor environment.[45,46] There is an idea that environmental conditions may contribute to asthma occurrences.[47-49]

The current study was planned to use GIS to determine

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the association among the spatial dimensions of asthma and its environmental controlling factors in Karachi.

Materials and Methods

The cross-sectional study was conducted in Landhi and Korangi towns of Karachi from 2011 to 2013. Based on literature review, a list of asthma environmental triggers[50-140] were compiled (Table-1) that helped in designing the study and preparing environmental parameters having proven relationship with asthma (Figure-1).

Karachi, the mega city of Pakistan, is administratively divided into 18 towns and cantonment areas. For detailed field investigation and environmental data collection, Landhi Town and Korangi Town were selected. These towns are further divided in 21 union councils (UC), which is the smallest administrative unit in Pakistan. Both adjacent towns represent the typical environment and living conditions of Karachi (Figure-2).

Table-1: Parameters and variables used in asthma prone modelling.

S.No.	Parameters	Literature
1	Demographic factors	It includes:
		i. Gender[50-53]
		ii. Age groups[54-56]
		iii. Household size[57-59]
		iv. Earning and type of class[60-63]
		v. Characteristics of the houses[64-66]
		Language/Race/ethnic group[67-69]
2	Socio-economic factors	
		i. Type of occupation[70-72]
		ii. Literacy and Education[73-75]
		iii. Living since[76-78]
		iv. Seasonal dependencies of disease[79-81]
		v. Water Quality[82-84]
		vi. Moisture[85-87]
3	Indoor environment	
		i. Rats &cockroaches[88-90]
		ii. Plants[91-93]
		iii. Pets[94-96]
		iv. Energy source[97-99]
		v. Active /passive Smoking[100-102]
		vi. Ventilation[103-105]
		vii. Carpets[106-108]
4	Environmental Pollution	
		i. Air pollutants[109-111]
		ii. Water Pollutants[112-114]
		iii. Soil Pollutants[115-117]
5	Asthma Aetiology	
		i. Symptoms[118-120]
		ii. Type of disease[121,122]
		iii. Causes of disease[123-125]
		iv. Consultation[126-128]
		v. Reason of symptoms/ Difficulty in respiration[129-132]
		vi. Time period/Duration[133-135]
		vii. Specific reason of disease[136-140]

For collecting environmental data, QuickBird satellite imagery was used from Google Earth to develop the digital base maps of the study area on a larger scale of 1:5,000 by using ArcGIS 10 software that mainly consists of roads, points of interests (POIs) and land use / land cover (LULC). Published administrative maps of the City District Government Karachi (CDGK) were also used to define the administrative boundaries, which are digitised as vector layers.

Asthma prevalence and the socio-environmental conditions were appraised through an in-depth questionnaire. The instrument used was an extended version of the questionnaire developed by the International Union against Tuberculosis and Lung Disease (IUATLD) for such diseases validated by a pioneer study.[141] The IUATLD questionnaire is focussed on the investigation of asthma prevalence in the community. However, we extended the questionnaire by adding socio-environmental questions.[50-140]

A few research assistants were trained for data collection, and pilots were run to improve the content of the questionnaire, avoid errors/omissions and to get effectiveness of results. Almost 80% interviewers were female who were a great help in executing the questionnaire in the selected study area due to cultural sensibilities.

Every effort was made to cover diversity in environmental settings, including planned and slum neighbourhoods, proximity to industrial units, and roadside retail outlets. For managing field execution, stratified random sampling was employed with a sample size of 0.1% of the total respondents (n=987). Households of each UC were considered for preparing spatially location-based distributed sample size that was mapped and analysed thereafter.

Informed consent was obtained from the subjects as the questionnaire was explained in both verbal and written forms in Urdu, the native language, and validated prior to execution by a translation expert. The identity of individuals and data storage was maintained confidentially as per the guidelines of the Departmental Research Committee (DRC), Department of Geography, and University of Karachi.

Besides qualitative survey, ambient air, drinking water and surface soil were analysed to trace the air pollutants and heavy metals. These included carbon monoxide (CO), sulphur dioxide (SO2), nitrogen oxide (NO), nitrogen

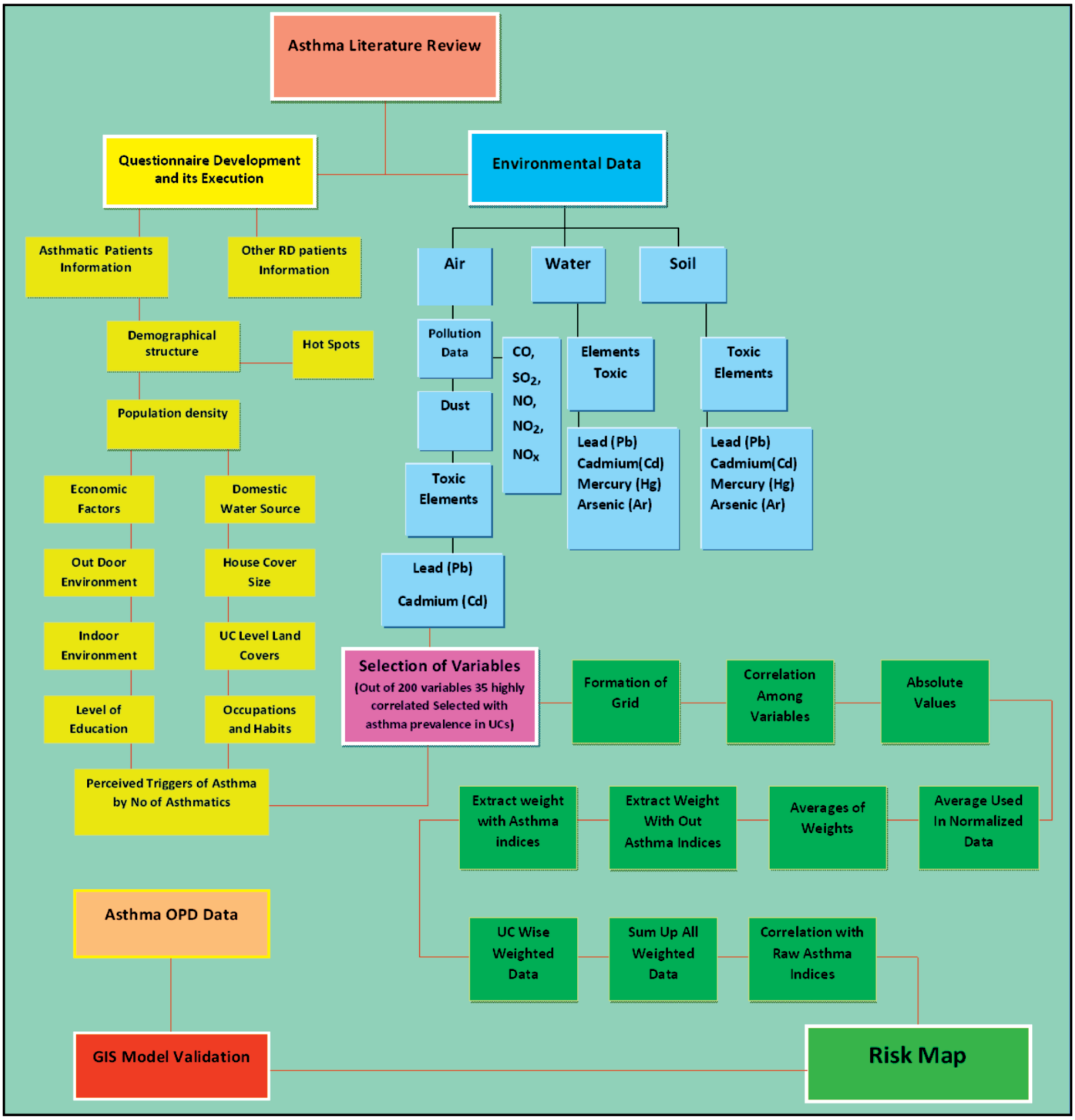
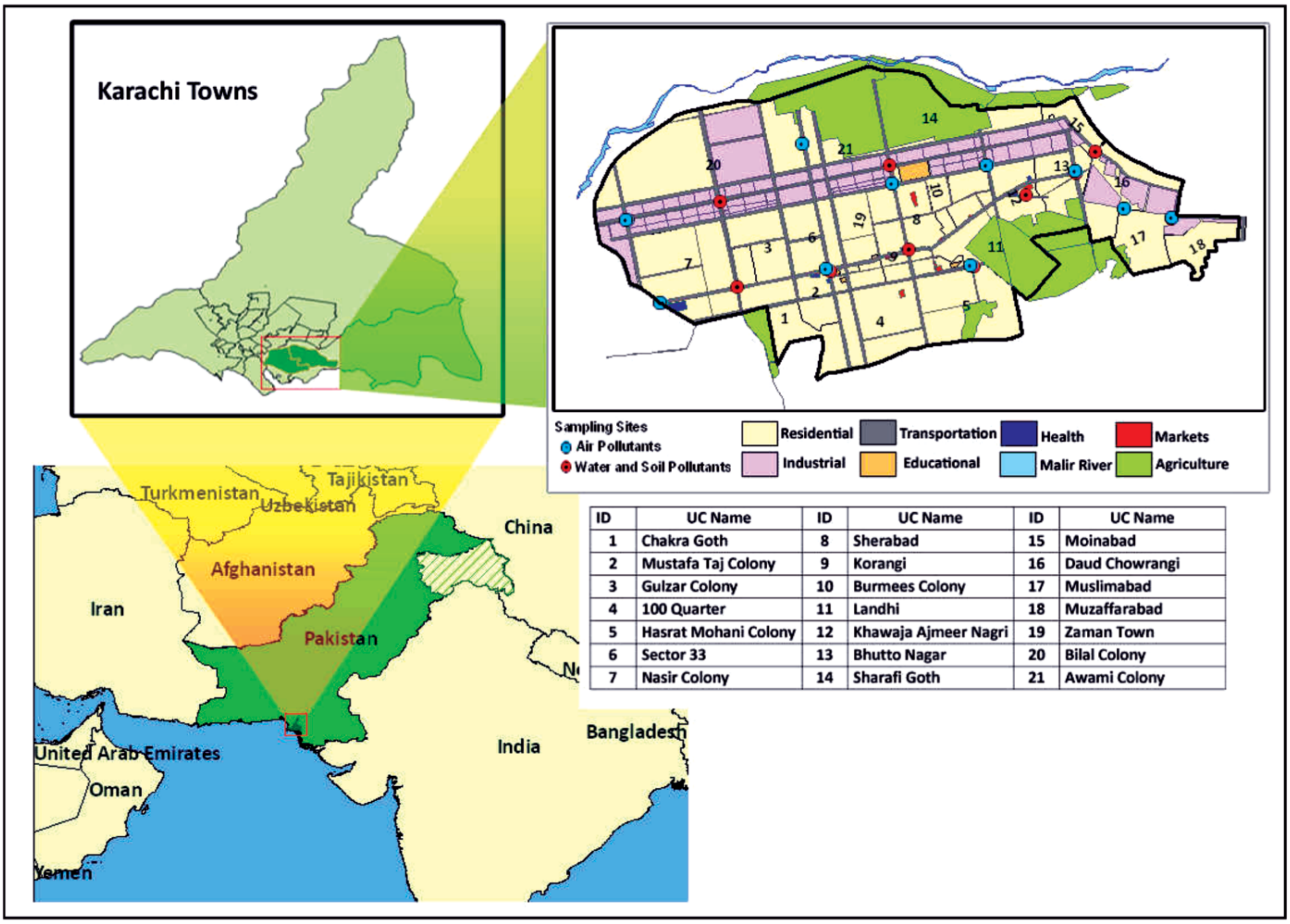


Figure-1: Flow Chart.

dioxide (NO2), nitrogen oxides (NOx), total suspended particles (TSPs), lead (Pb) and cadmium (Cd) for air, and for the soil and water, toxic elements like Pb, Cd, arsenic (As) and mercury (Hg). Soil and water data was collected from 12 selected locations, which are distributed in residential, industrial and commercial areas, whereas air was analysed at 10 sample locations on major road intersections and industrial areas.

Multi-criteria evaluation (MCE) technique was used to assess the asthma-prone environment. This technique uses the spatial relationships among variables that increase the



ID	UC Name	ID	UC Name	ID	UC Name
1	Chakra Goth	8	Sherabad	15	Moinabad
2	Mustafa Taj Colony	9	Korangi	16	Daud Chowrangi
3	Gulzar Colony	10	Burmees Colony	17	Muslimabad
4	100 Quarter	11	Landhi	18	Muzaffarabad
5	Hasrat Mohani Colony	12	Khawaja Ajmeer Nagri	19	Zaman Town
6	Sector 33	13	Bhutto Nagar	20	Bilal Colony
7	Nasir Colony	14	Sharafi Goth	21	Awami Colony

Figure-2: Distribution of land use and pollutants sampling sites in the study area.

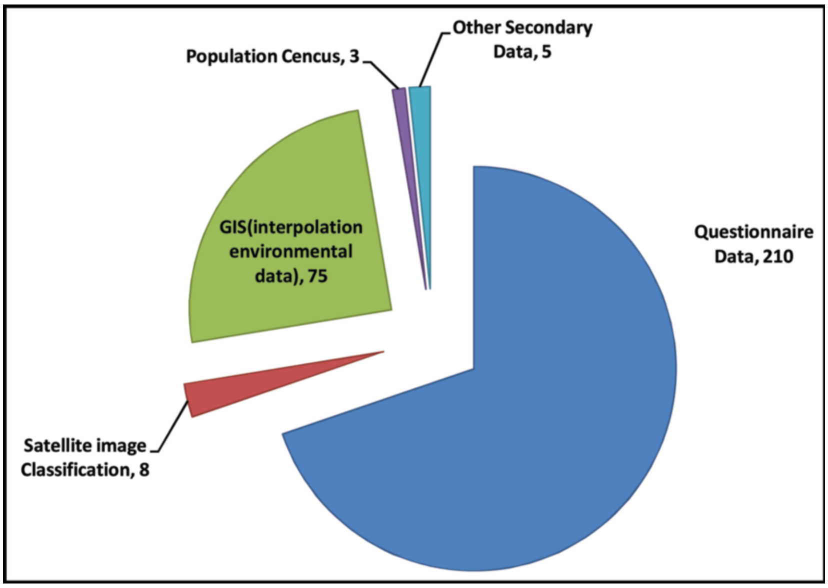


Figure-3: Data sources distribution with number of variables.

interpretability of spatial information.[142,143] We utilised the weighted sum function in ArcGIS 10 in the spatial analyst tool.[143,148] It utilises the following equation to assess the weighted sum:

$$R = \Sigma W_i \times X_i \qquad (1)$$

Where R = Risk; W_i = weight of factor I; and X_i = standardised score of factor i.

The adopted analytical techniques were already implemented by studies in both developed and developing countries.[144-148] Based on literature search, we prepared multiple parameters for a combined, asthma-prone appraisal system. Initially, more than 200 socio-environmental variables were developed and tested in relation to the prevalence of asthma in the study area (Figure-3). The collected data

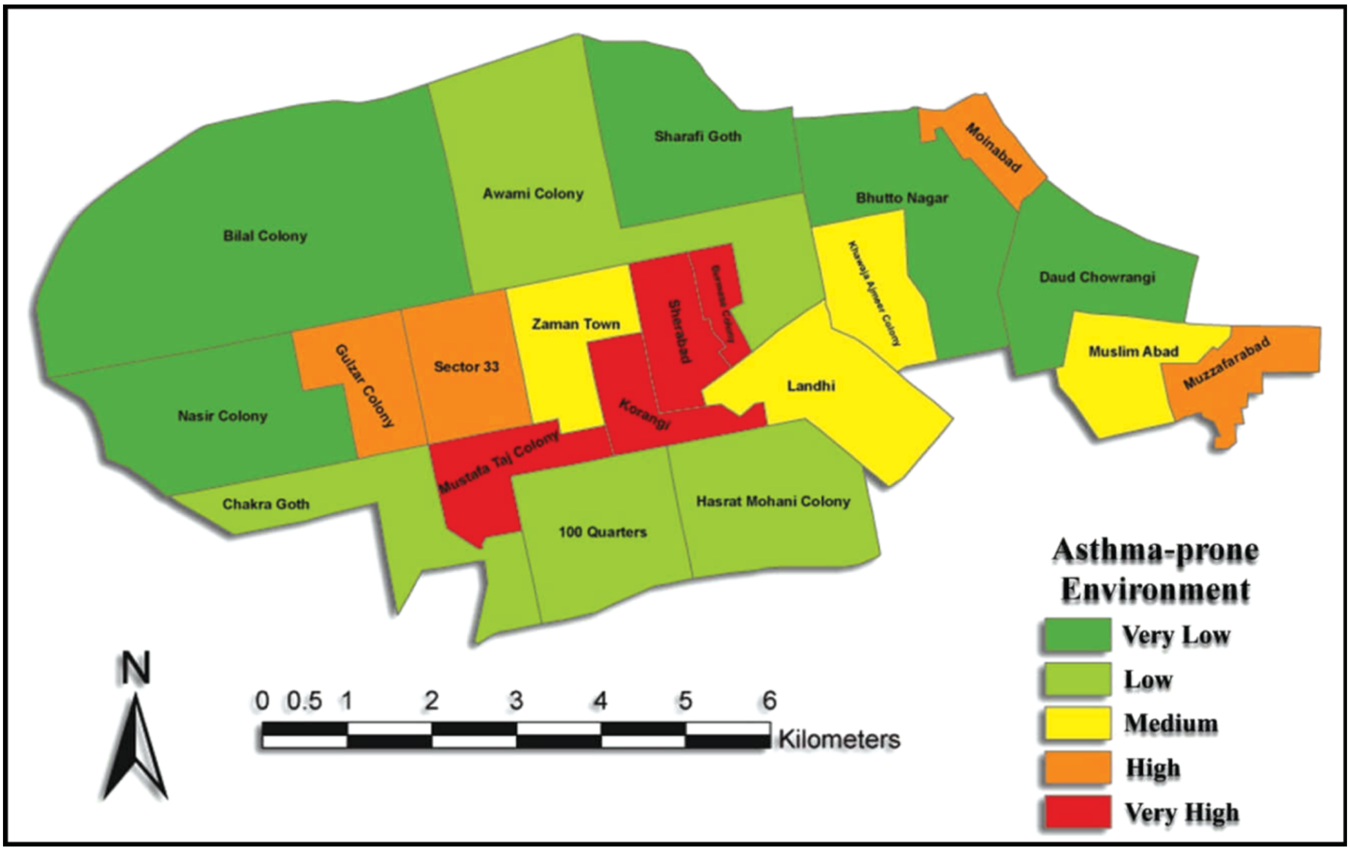


Figure-4: Asthma-prone environment divisions.

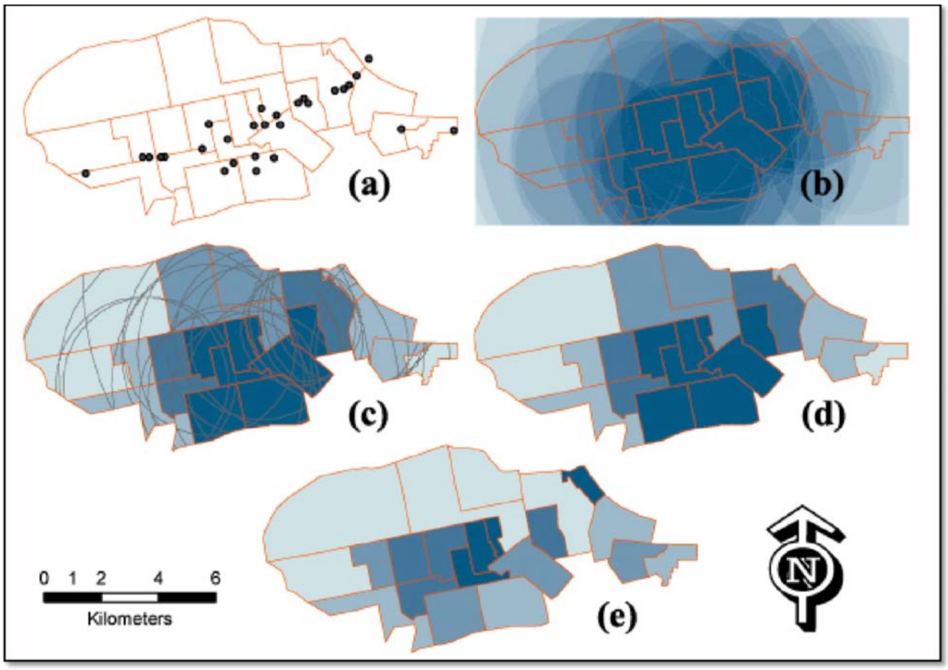


Figure-5: (a) Asthma Clinics Distribution (b) Buffer of Potential Patient Coverage (c) Zonal Statistics by Overlay Analysis (d) Evaluated Asthma outpatient department (OPD) (e) Normalised Asthma OPD.

was compiled on a standard template in MS Excel to extract statistical results, i.e. correlation, frequencies of data, etc. ArcGIS 10 software was used to generate interpolated surfaces for each data layer, which was later summarised for each UC. However, we tested their relationship with asthma prevalence by calculating Spearman's coefficient correlation. As per our threshold selection criteria (i.e. $r>0.3$ or $r<0.3$) ($p<0.05$), 32 variables established their significant relationship with the prevalence of asthma and were finalised for using in MCE in the form of spatial overlays.

The strength of correlations was prioritised among standardised criterion variables regardless of

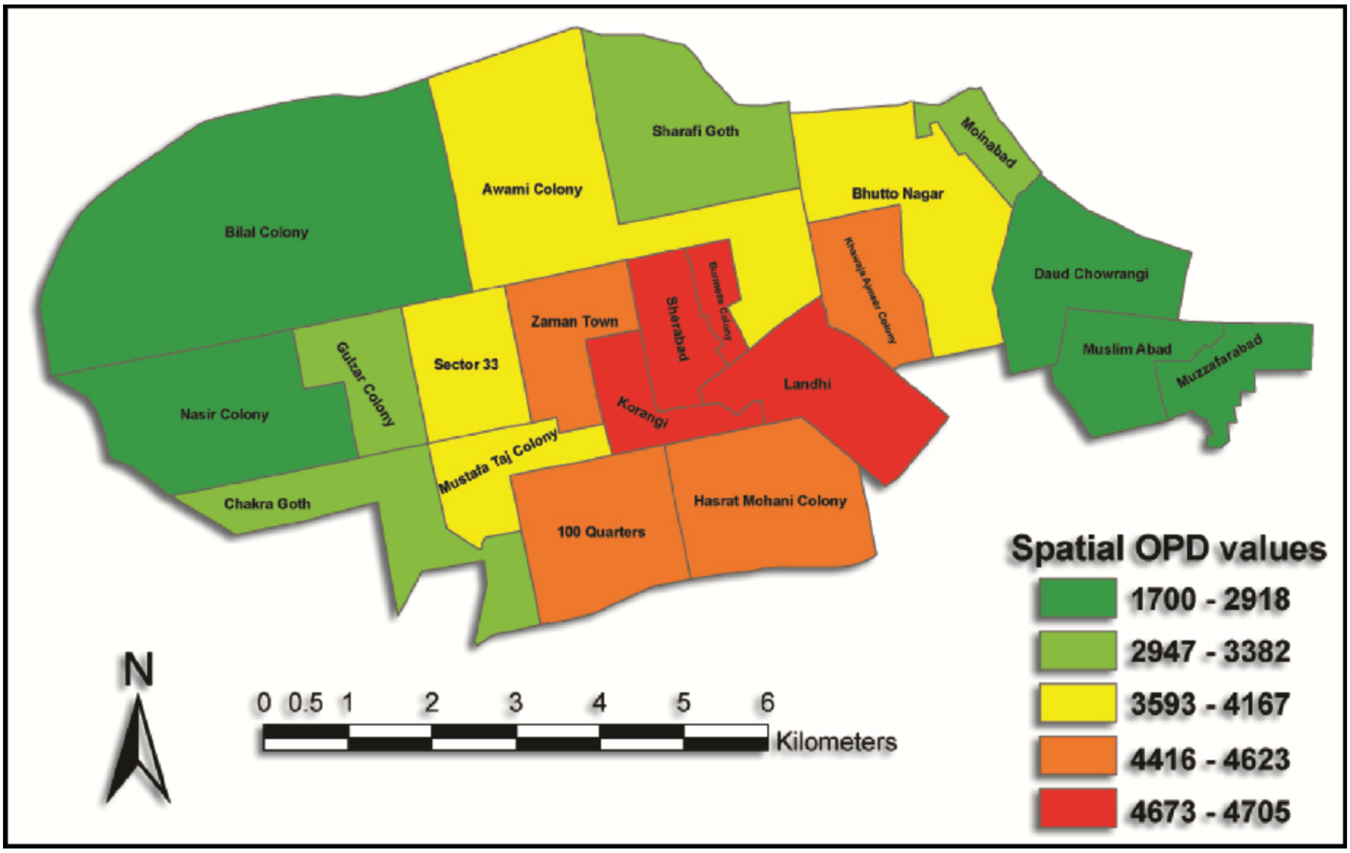


Figure-6: Average outpatient department (OPD) distribution (number of patients).

the direction. Hence, two-tailed Spearman's correlation method was applied. All variables demonstrated their strength of interaction on spatial canvas. We utilised the total sum and weighted them according to their respective proportions for final risk assessment. Weights are assigned to each criterion variable (overlays) as an indication of the intended contribution of that layer.

MCE analysis procedures require the standardisation of dataset values. We normalised data in two steps. First, we converted all the selected variables into measurement per acre. In the second step, we re-scaled the value of each variable with a value range of 1 to 10, where 1 represents the lowest and 10 the highest for consideration of risk. The ranges of possible values were divided into 10 groups, so that the each group contains the same range of frequencies. This grouping method was useful to focus variation in the middle values of the distribution, because the intervals are usually wider at the extremes.[149-151]

The outcome of risk evaluation was validated through field measurements of asthma outpatient departments (OPDs) for 24 months duration from major hospitals and clinics. The obtained results were validated by asthma OPD data from various local hospitals and clinics. Model validation was done in 5 steps: Asthma OPD data was obtained from hospitals and clinics with patient addresses; locations of asthma patients were geo-coded using their addresses; UC-wise asthma patients' density was calculated to have normalised value (asthmatics per unit area); level of asthma-prone environment was visually compared with the monitored asthma patients in all UCs; and, finally, comparing asthma-prone environment in UCs and OPD statistics, almost similar areas emerged, suggesting that the model of asthma assuming areas stood verified (Figures-5-6).

Results

There was a strong positive correlation among asthma prevalence with land cover, like vegetation, toxic elements, like Pb and Cd, poisonous gases, especially CO, and socioeconomic variables like household density and occupation (Table-2). Asthma prevalence was occurring in densely inhabited area, especially near commercial streets and busy roads of Landhi and Korangi towns. Spatial distribution of the appraised areas among UCs

Table-2: Finalised overlay grids.

1. Land- cover Classification Grid (LCCG)	.481*	17. Rats Intensity Grid (RatG)	.801**
2. Land- Use Classification Grid (LUCG)	-.454*	18. Roaches Intensity Grid (RoCG)	.753**
3. Averages of CO Grid (ACOG)	.671**	19. Indoor Plants Intensity Grid (PlantG)	.734**
4. Averages of SO2 Grid (ASO2G)	.488*	20. Domestic Birds Intensity Grid (BirdG)	.704**
5. Averages of NO Grid (ANOG)	.471*	21. Risky Occupation Intensity Grid (RisOccG)	.882**
6. Averages of NO2 Grid (ANO2G)	.476*	22. Boring Water utilization Grid (BorWtG)	0.32
7. Averages of Dust Grid (ADUG)	.705**	23. Municipal Water utilization Intensity Grid (OThWtG)	.523*
8. Averages of Cd in Dust Grid(ACdDG)	.711**	24. House Holds Density Grid (HholDG)	.760**
9. Averages of Pb in Dust Grid(APbDG)	.725**	25. Tobacco Addicts Intensity Grid (TobAddG)	0.44
10. Averages of Cd in water Grid(ACdWG)	.705**	26. Density of Houses less than 120sqyds Grid (HL120G)	.760**
11. Averages of As in water Grid(AAsWG)	.650**	27. Allergy Rhinitis Distribution Grid (AllDG)	.449*
12. Averages of Cd in soil Grid(ACdSG)	.753**	28. Bronchitis Distribution Grid (BrDG)	.755**
13. Averages of Pb in soil Grid(APbSG)	.701**	29. COPD Distribution Grid (CopdDG)	.593**
14. Intensity of Kitchen fumes in house Grid(KFIG)	.885**	30. Tb Distribution Grid (TbDG)	.481*
15. Intensity of No or low ventilation in house Grid(VNoG)	.893**	31. Lung Cancer Distribution Grid (LuCDG)	.331*
16. Intensity of Dampness Grid (DamG)	.815**	32. Asthma Distribution Grid (AsDG)	1.0

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table-3: Weighted sum and asthma indices with risk potential.

UCs	Area (acres)	Population	Asthma Prevalence (%)	Weighted Sum	Risk	Population proportion
Burmese Colony	143	53,043	9	8	Very HIGH Risk	40%
Korangi	325	61,309	6	5	Very HIGH Risk	
Sherabad	346	62,071	10	5	Very HIGH Risk	
Mustafa Taj Colony	410	59,579	9	4	Very HIGH Risk	
Gulzar Colony	428	63,474	11	4	High Risk	
Moinabad	221	44,996	21	4	High Risk	
Sector 33	510	61,661	6	4	High Risk	
Muzzafarabad	337	62,797	14	4	High Risk	
Khawaja Ajmeer Colony	451	61,326	2	3	Medium Risk	18%
Landhi	721	53,196	5	3	Medium Risk	
Muslim Abad	466	42,307	16	3	Medium Risk	
Zaman Town	495	60,408	3	3	Medium Risk	
100 Quarters	789	57,867	8	3	Low Risk	19%
HasratMohani Colony	897	58,084	9	3	Low Risk	
Awami Colony	1745	60,660	15	2	Low Risk	
Chakra Goth	785	61,184	9	2	Low Risk	
Bhutto Nagar	1034	54,110	9	2	Very Low Risk	23%
Bilal Colony	2914	62,449	6	2	Very Low Risk	
Daud Chowrangi	748	61,787	13	2	Very Low Risk	
Nasir Colony	1079	61,798	4	2	Very Low Risk	
Sharafi Goth	952	49,146	12	2	Very Low Risk	

suggested that almost 40% of the study population were living in the extremely vulnerable area (Table-3).

There were extremely high asthma risks in the centre of the study area that comprised the densely populated administrative units. Besides population density, most commercial area, educational and entertainment facilities and one of the most important explanations may be a high density of traffic as this region, having most frequent used road by the name of 12000 (road name), is positioned as the hub of the entire study area. Many urban commercial activities were located in this region. This region, having iron and wood markets as well, had respiratory diseases including asthma.

Various factors such as exposure to ambient environment, inappropriate land use, illegal economic activities, loose enforcement of city codes, and limited utility services contributed to asthma in the study area. Timber manufacturing facilities, such as milling and production of

Figure-7: Unhygienic environmental conditions and high population density promoting the respiratory diseases.

wood panels, wood blocks, ladders and other commercial products, were located openly at the roadside affecting the local population and passers-by (Figure-7A-B). The workers do not care about the wood dust and chemical fumes generated from woodworking and inhale them continuously, without any precautionary measures. Furthermore, due to the temporally extended road construction activities by City District Government of Karachi (CDGK), asthma-prone areas are facing heavy concentration of dust due to heavy vehicle movements and noxious air pollutants (Figure-7C-D). Open drains carrying industrial waste passing through the commercial areas and the residential neighbourhoods provided intimidating environmental conditions that are ideal for the prevalence and dispersion of asthma (Figure-7E-F). Whereas the crowded markets, busy stops, congested roads and overall congestion in the area are also the root causes of the dispersion of respiratory diseases like asthma (Figure-7G-H).

Discussion

Recently, asthma prevalence is increasing among all age groups throughout the world. Karachi, the biggest city of Pakistan, is also facing the resurgence of asthma due to unprecedented environmental deterioration and lack of governance. There are almost no studies in literature that assessed the role of physical and social environmental settings for nurturing the asthma-prone environment in Karachi.

The study area was initially designed in 1960s with a small residential population. The initial planning is disturbing continuously and now it has become a mixture of planned and unplanned slum in many economically significant areas. New shape of the area is having many problems, such as concentration in one area of commercial markets, manufacturing units, educational and recreational units in the same place that enhance traffic volume and abnormal congestions. So overall situation is unpleasant and authorities are losing their ability to implement laws of planning, traffic and environmental setting. Although over 70% of the area of both these towns is designated as residential by the local development authority, but all types of major urban activities are found side by side here, which was the main reason for choosing these two towns. Within residential areas, land use of commercial markets, educational institutions, timber manufacturing and other traffic attractors (mosques, hospitals, wedding halls, community centre) exist. This has happened through gradual transformation of land use over an extended period of time. The residents are less literate regarding their civic responsibilities. Weak implementation of environmental and building by-laws by local authorities have resulted in chaotic land use all over the city.

Concerning air pollution in the study area, industrial units and automobile exhaust are two main sources.[152] Many environmental toxic chemicals are released in the air by industries. Growing number of vehicles use lead-laced gasoline, poor model of vehicles, poor maintenance of vehicles, use of defective silencers, poor road conditions, rash driving, etc. are the major causes of high concentration of air pollutants in the environment of this area.[153,154] There is a growing need to formulate proper regulatory laws to limit emission of gaseous pollutant from individual vehicles and implemented forcefully by on-spot checking. Traffic geometry also plays an important role. With time, the vehicles on the roads and the transport routes have become dense and congested producing pollution. Faulty and worn out vehicles should be removed from the roads.[155]

The other reasons of high concentration of air pollutants on the streets are poor model of vehicles, poor maintenance, narrow roads and uneven road surfaces, rash driving, poor education of vehicle drivers, especially commercial vehicle drivers, poor geometrics, frequent traffic jams and congestion aggravated the situation. During traffic jams or signal light the air pollutants, including carbon monoxide concentration, shoots up abruptly within frictions of a minute and becoming a health hazard for human beings.[156] The concentration of air pollutants at a place varies with traffic density and type and condition of vehicles in the given traffic stream. Social and cultural factors also play an important role, like during the festive Eid occasion more people come to the markets, and in summer vacations, students are free to play long hours and that also creates congestion and traffic flow. Seasonal changes in weather conditions higher the wind velocity and more open area around the location lower the concentration of pollutants and several other harmful noxious wastes that results respiratory diseases.[157,158]

Constant exposure to high-level air pollutants may result in a variety of adverse effects on roadside traders and workers. The reasons of high air pollutants and other gaseous pollutants in ambient air are lack of regulatory laws to gaseous pollutants in the ambient air on the roads.[159] Indoor air quality is also affected by the expansion of industrial units, construction of buildings, utility lines, roads, and housing. Most of the slum areas are in the periphery of the study area with high level of population density and low level of standard of living. Lack of clean environment and medical facilities for the poor population results in asthma and other respiratory diseases.[160]

There is a need of a proper policy to cope with this situation which may reduce future respiratory patients. Policy development will need to cover all important aspects of public health system, from developing and strengthening public health infrastructure like surveillance systems, developing national agenda for asthma and pollution research, access to health care issues, generating local capacity to handle environmental and healthcare issues, and improving at local, provincial and national levels. Implementing these recommendations will require involvement of many stakeholders and could only succeed if properly coordinated at the federal, provincial, and local community level, and within and outside the healthcare delivery system.

Conclusion

In a developing country, like Pakistan, data about diseases and their environmental causes is difficult to collect. Spatial technologies such as high-resolution remote sensing, GIS and other allied tools, could provide not only relatively accurate information but also data management and analysis platform with precise locational accuracy. Further, it was evident that an integrated computing platform, at larger scales, could effectively be used to monitor the menace of respiratory diseases like asthma.

Disclaimer: The datasets generated and/or analysed during the study are not publicly available due to on-going research, but are available from the corresponding author on reasonable request.

Conflict of Interest: None.

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References

1. Meier T, Gräfe K, Senn F, Sur P, Stangl GI, Dawczynski C, März W, Kleber ME, Lorkowski S. Cardiovascular mortality attributable to dietary risk factors in 51 countries in the WHO European Region from 1990 to 2016: a systematic analysis of the Global Burden of Disease Study. Eur J Epidemiol. 2019; 34:37-55.
2. Carroll K. Socioeconomic status, race/ethnicity and asthma in youth 2013, pp 1180-1.
3. Khan IA, Arsalan MH, Siddiqui MF, Zeeshan S, Shaukat SS. Spatial association of asthma and vegetation in Karachi: a Gis perspective. Pak J Bot. 2010 ;42:3547-54.
4. PCS. The Need for Asthma Guidelines. Pakistan Chest Society; 2009.
5. Marans RW. 2012. Quality of urban life studies: An overview and implications for environment-behaviour research. Procedia-Soc Behav Sci 2012;35:9-22.
6. Brooker S, Hay SI, Bundy DA. Tools from ecology: useful for evaluating infection risk models? Trends Parasitol. 2002 ;18:70-4.
7. Claborn DM. Remote Sensing and Geographic Information Systems as Decision Support Tools for Malaria Control in the Republic of Korea. Uniformed Services University Of The Health Sciences Bethesda United States; 2001 May 30.
8. Sipe NG, Dale P. Challenges in using geographic information systems (GIS) to understand and control malaria in Indonesia. Malaria J. 2003;2:36.
9. Parra JL, Graham CC, Freile JF. Evaluating alternative data sets for ecological niche models of birds in the Andes. Ecography. 2004 ;27:350-60.
10. Peterson AT, Martínez-Campos C, Nakazawa Y, Martínez-Meyer E. Time-specific ecological niche modeling predicts spatial dynamics of vector insects and human dengue cases. Transac Royal Soc Trop Med Hygiene. 2005;99:647-55.
11. Sugumaran R, Larson SR, DeGroote JP. Spatio-temporal cluster analysis of county-based human West Nile virus incidence in the continental United States. Int J Health Geographics. 2009;8:43.
12. Beck LR, Lobitz BM, Wood BL. Remote sensing and human health: new sensors and new opportunities. Emerg Infect Dis. 2000;6:217.
13. Jerrett M, Burnett R, Goldberg M, Sears M, Krewski D, Catalan R, et al. Spatial analysis for environmental health research: concepts, methods, and examples. J Toxicol Environ Health Part A. 2003;66:1783-810.
14. Kazmi SJ, Usery EL. Application of remote sensing and GIS for the monitoring of diseases: a unique research agenda for geographers. Remote Sensing Rev. 2001;20:45-70.
15. Lawson AB. Disease map reconstruction. Stat Med. 2001 ;20:2183-204.
16. Lim S, Heleinski B, Lee H. Geocorrelation of Contributing Factors to Asthma in New South Wales. Int J Geoinformatics. 2010 ;6(4).
17. Mushinzimana E, Munga S, Minakawa N, Li L, Feng CC, Bian L, et al. Landscape determinants and remote sensing of anopheline mosquito larval habitats in the western Kenya highlands. Malaria J 2006;5:13.
18. Peterson AT, Robbins A, Restifo R, Howell J, Nasci R. Predictable ecology and geography of West Nile virus transmission in the central United States. J Vector Ecol. 2008;33:342-52.
19. Andersen I, Korsgaard J. Asthma and the indoor environment: assessment of the health implications of high indoor air humidity. Environ Int. 1986;12:121-7.
20. Curtis L, Rea W, Smith-Willis P, Fenyves E, Pan Y. Adverse health effects of outdoor air pollutants. Environ Int 2006;32:815-30.
21. Henderson AJ, Sherriff A, Northstone K, Kukla L, Hruba D. Pre-and postnatal parental smoking and wheeze in infancy: cross cultural differences. Eur Resp J. 2001;18:323-9.
22. Hunt A, Crawford JA, Rosenbaum PF, Abraham JL. Levels of household particulate matter and environmental tobacco smoke exposure in the first year of life for a cohort at risk for asthma in urban Syracuse, NY. Environ Int. 2011;37:1196-205.
23. Johansson E, Reponen T, Vesper S, Levin L, Lockey J, Ryan P, et al. Microbial content of household dust associated with exhaled NO in asthmatic children. Environ Int. 2013;59:141-7.
24. Al-Kubaisy W, Ali SH, Al–Thamiri D. Pediatric asthma and its relation to sociodemographic factors in Baghdad. Asian J Environ Behav Studies. 2017;2:75-84.
25. Raja S, Xu Y, Ferro AR, Jaques PA, Hopke PK. Resuspension of indoor aeroallergens and relationship to lung inflammation in asthmatic children. Environ Int. 2010;36:8-14.
26. Sarafino EP, Gates M, DePaulo D. The role of age at asthma diagnosis in the development of triggers of asthma episodes. J Psychosomatic Res. 2001;51:623-8.
27. Cohen AJ, Ross AH, Ostro B, Pandey KD, Krzyzanowski M, Künzli N, et al. The global burden of disease due to outdoor air pollution. J Toxicol Environ Health Part A. 2005;68:1301-7.
28. Dell SD, Jerrett M, Beckerman B, Brook JR, Foty RG, Gilbert NL, et al. Presence of other allergic disease modifies the effect of early childhood traffic-related air pollution exposure on asthma

prevalence. Environ Int. 2014;65:83-92.
29. Ito K, D THURSTON GE, Nadas A, Lippmann M. Monitor-to-monitor temporal correlation of air pollution and weather variables in the North-Central US. J Expos Sci Environ Epidemiol. 2001;11:21.
30. Kim KH, Jahan SA, Kabir E. A review on human health perspective of air pollution with respect to allergies and asthma. Environ Int. 2013;59:41-52.
31. Maantay J. Asthma and air pollution in the Bronx: methodological and data considerations in using GIS for environmental justice and health research. Health Place. 2007;13:32-56.
32. Mishra V. Effect of indoor air pollution from biomass combustion on prevalence of asthma in the elderly. Environ Health Perspec. 2003 ;111:71.
33. Crocker DD, Kinyota S, Dumitru GG, Ligon CB, Herman EJ, Ferdinands JM, et al, Task Force on Community Preventive Services. Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a community guide systematic review. Am J Prevent Med. 2011;41:S5-32.
34. Du Z, Mo J, Zhang Y. Risk assessment of population inhalation exposure to volatile organic compounds and carbonyls in urban China. Environ Int. 2014;73:33-45.
35. Giroux M, Bremont F, Ferrieres J, Dumas JC. Exhaled NO in asthmatic children in unpolluted and urban environments. Environ Int 2001;27:335-40.
36. Jung KH, Hsu SI, Yan B, Moors K, Chillrud SN, Ross J, et al. Childhood exposure to fine particulate matter and black carbon and the development of new wheeze between ages 5 and 7 in an urban prospective cohort. Environ Int. 2012;45:44-50.
37. Marans RW, Stimson RJ, editors. Investigating quality of urban life: Theory, methods, and empirical research. Springer Science & Business Media; 2011.
38. Patel MM, Miller RL. Air pollution and childhood asthma: recent advances and future directions. Curr Opin Pediatr. 2009;21:235.
39. Peden DB. Air pollution in asthma: effect of pollutants on airway inflammation. Ann Allergy Asthma Immunol. 2001;87:12-7.
40. Pepys J. Chemical dusts, vapours, and fumes causing asthma. Environ Int. 1982;8:321-5.
41. Peters A, Dockery DW, Muller JE, Mittleman MA. Increased particulate air pollution and the triggering of myocardial infarction. Circulation. 2001 ;103:2810-5.
42. Sarpong SB, Hamilton RG, Eggleston PA, Adkinson Jr NF. Socioeconomic status and race as risk factors for cockroach allergen exposure and sensitization in children with asthma. Journal of Allergy and Clinical Immunology. 1996 Jun 1;97(6):1393-401.
43. Chen Y, Craig L, Krewski D. Air quality risk assessment and management. J Toxicol Environ Health, Part A. 2008;71:24-39.
44. Du B, Price AE, Scott WC, Kristofco LA, Ramirez AJ, Chambliss CK, et al. Comparison of contaminants of emerging concern removal, discharge, and water quality hazards among centralized and on-site wastewater treatment system effluents receiving common wastewater influent. Sci Total Environ 2014;466:976-84.
45. Clark NA, Demers PA, Karr CJ, Koehoorn M, Lencar C, Tamburic L, et al. Effect of early life exposure to air pollution on development of childhood asthma. Environ Health Perspect. 2009;118:284-90.
46. Koenig JQ. Air pollution and asthma. J Allerg Clin Immunol. 1999;104:717-22.
47. DiFranza JR, Aligne CA, Weitzman M. Prenatal and postnatal environmental tobacco smoke exposure and children's health. Pediatrics. 2004;113:1007-15.
48. Kim JH, Oh JW, Lee HB, Kim SW, Chung HL, Kook MH, et al. Evaluation of the association of vegetation of allergenic plants and pollinosis with meteorological changes. Allergy, Asthma Resp Dis. 2014;2:48-58.
49. Nurmagambetov TA, Barnett SB, Jacob V, Chattopadhyay SK, Hopkins DP, Crocker DD, et al, Task Force on Community Preventive Services. Economic value of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a Community Guide systematic review. Am J Prevent Med. 2011 ;41:S33-47.
50. Kamran A, Hanif S, Murtaza G. Risk factors of childhood asthma in children attending Lyari General Hospital. J Pak Med Assoc 2015;65:647-50.
51. Postma DS. Gender differences in asthma development and progression. Gender Med 2007;4:S133-46.
52. Siroux V, Curt F, Oryszczyn MP, Maccario J, Kauffmann F. Role of gender and hormone-related events on IgE, atopy, and eosinophils in the Epidemiological Study on the Genetics and Environment of Asthma, bronchial hyperresponsiveness and atopy. J Allergy Clin Immunol. 2004 ;114:491-8.
53. Langdeau JB, Day A, Turcotte H, Boulet LP. Gender differences in the prevalence of airway hyperresponsiveness and asthma in athletes. Resp Med. 2009;103:401-6.
54. Fagan JK, Scheff PA, Hryhorczuk D, Ramakrishnan V, Ross M, Persky V. Prevalence of asthma and other allergic diseases in an adolescent population: association with gender and race. Ann Allergy Asthma Immunol. 2001;86:177-84.
55. Vicendese D, Abramson MJ, Dharmage SC, Tang ML, Allen KJ, Erbas B. Trends in asthma readmissions among children and adolescents over time by age, gender and season. J Asthma. 2014;51:1055-60.
56. Obaseki D, Potts J, Joos G, Baelum J, Haahtela T, Ahlström M, et al. The relation of airway obstruction to asthma, chronic rhinosinusitis and age: results from a population survey of adults. Allergy. 2014;69:1205-14.
57. Tai A, Tran H, Roberts M, Clarke N, Gibson AM, Vidmar S, et al. Outcomes of childhood asthma to the age of 50 years. J Allerg Clin Immunol. 2014;133:1572-8.
58. Ehrlich RI, Du Toit D, Jordaan E, Zwarenstein M, Potter P, Volmink JA, et al. Risk factors for childhood asthma and wheezing. Importance of maternal and household smoking. Am J Respir Crit care Med. 1996 ;154:681-8.
59. Zock JP, Plana E, Jarvis D, Antó JM, Kromhout H, Kennedy SM, et al. The use of household cleaning sprays and adult asthma: an international longitudinal study. Am J Resp Crit Care Med. 2007;176:735-41.
60. Gupta D, Aggarwal AN, Chaudhry K, Chhabra SK, D'Souza GA, Jindal SK. Household environmental tobacco smoke exposure, respiratory symptoms and asthma in non-smoker adults: a multicentric population study from India. Women. 2006;35183:52-0.
61. Hedlund U, Erikson K, Rönmark E. The socio-economic status is related to the incidence of asthma and respiratory symptoms in adults. Eur Resp J. 2006;28:303-10.
62. Weiss KB, Gergen PJ, Hodgson TA. An economic evaluation of asthma in the United States. N Engl J Med. 1992;326:862-6.
63. Accordini S, Corsico A, Cerveri I, Gislason D, Gulsvik A, Janson C, et al. The socio-economic burden of asthma is substantial in Europe. Allergy. 2008;63:116-24.
64. Bosello F, Roson R, Tol RS. Economy-wide estimates of the implications of climate change: Human health. Ecological Economics. 2006 ;58:579-91.
65. Spengler J, Neas L, Nakai S, Dockery D, Speizer F, Ware J, et al. Respiratory symptoms and housing characteristics. Indoor air. 1994 ;4:72-82.
66. Douglas MJ, Conway L, Gorman D, Gavin S, Hanlon P. Developing principles for health impact assessment. J Public Health. 2001;23:148-54.
67. Crocker DD, Kinyota S, Dumitru GG, Ligon CB, Herman EJ,

Ferdinands JM, et al, Task Force on Community Preventive Services. Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a community guide systematic review. Am J Prevent Med 2011;41:S5-32.
68. Miller JE. The effects of race/ethnicity and income on early childhood asthma prevalence and health care use. Am J Public Health. 2000;90:428.
69. Zahran HS, Bailey C. Factors associated with asthma prevalence among racial and ethnic groups—United States, 2009–2010 behavioral risk factor surveillance system. J Asthma. 2013;50:583-9.
70. Camacho-Rivera M, Kawachi I, Bennett GG, Subramanian SV. Associations of neighborhood concentrated poverty, neighborhood racial/ethnic composition, and indoor allergen exposures: a cross-sectional analysis of Los Angeles households, 2006–2008. J Urban Health. 2014 ;91:661-76.
71. Malo JL, Chan-Yeung M, Bernstein DI, editors. Asthma in the workplace. CRC Press; 2013.
72. Tarlo SM, Lemiere C. Occupational asthma. N Engl J Med. 2014;370:640-9.
73. Cartier A, Lemiere C, Sava F. A Cluster Analysis Of Work-Related Asthma. Am J Respir Crit Care Med. 2014; 189:A5209.
74. DeWalt DA, Dilling MH, Rosenthal MS, Pignone MP. Low parental literacy is associated with worse asthma care measures in children. Ambul Pediatr. 2007;7:25-31.
75. Poureslami IM, Rootman I, Balka E, Devarakonda R, Hatch J, FitzGerald JM. A systematic review of asthma and health literacy: a cultural-ethnic perspective in Canada. Medscape Gen Med. 2007;9:40.
76. Radic SD, Milenkovic BA, Gvozdenovic BS, Zivkovic ZM, Pesic IM, Babic DD. The correlation between parental education and their knowledge of asthma. Allergologia et immunopathologia. 2014 ;42:518-26.
77. Smargiassi A, Goldberg MS, Wheeler AJ, Plante C, Valois MF, Mallach G, et al. Associations between personal exposure to air pollutants and lung function tests and cardiovascular indices among children with asthma living near an industrial complex and petroleum refineries. Environ Res. 2014;132:38-45.
78. Rovira E, Cuadras A, Aguilar X, Esteban L, Borràs-Santos A, Zock JP, et al. Asthma, respiratory symptoms and lung function in children living near a petrochemical site. Environ Res. 2014;133:156-63.
79. Koinis-Mitchell D, McQuaid EL, Seifer R, Kopel SJ, Esteban C, Canino G, et al. Multiple urban and asthma-related risks and their association with asthma morbidity in children. J Pediatr Psychol. 2007;32:582-95.
80. Cohen HA, Blau H, Hoshen M, Batat E, Balicer RD. Seasonality of asthma: a retrospective population study. Pediatrics. 2014;133:e923-32.
81. Hojo M, Iikura M, Mizutani T, Hirashima J, Sugiyama H. The Impact Of Co-Exisiting Seasonal Allergic Rhinitis By Japanese Cedar PollINOSis (sar-Jcp) Upon Asthma Control Status. InA33. CLINICAL ASTHMA I 2014 May (pp. A1327-A1327). American Thoracic Society.
82. Gerke AK, Yang M, Tang F, Foster ED, Cavanaugh JE, Polgreen PM. Association of hospitalizations for asthma with seasonal and pandemic influenza. Respirology. 2014;19:116-21.
83. Verhoeff AP, Burge HA. Health risk assessment of fungi in home environments. Ann allergy asthma & Immunol. 1997;78:544-56.
84. Achary GS, Mohanty SK, Ramakanta S. Status of ground water quality over the years in Cuttack city, Odisha, India. J Chem Pharmaceut Res. 2014;6:541-50.
85. Seth PK. Chemical contaminants in water and associated health hazards. In:Water and Health. New Delhi: Springer; 2014, pp 375-384.
86. Mendell MJ. Indoor dampness and mold as indicators of respiratory health risks, part 2: a brief update on the epidemiologic evidence. Proceed Indoor Air 2014;
87. Karvala K, Nordman H, Luukkonen R, Uitti J. Asthma related to workplace dampness and impaired work ability. Int arch Occup Environ Health 2014;87:1-1.
88. Quansah R, Jaakkola MS, Hugg TT, Heikkinen SA, Jaakkola JJ. Residential dampness and molds and the risk of developing asthma: a systematic review and meta-analysis. PloS one. 2012;7:e47526.
89. Wright RJ, Mitchell H, Visness CM, Cohen S, Stout J, Evans R, et al. Community violence and asthma morbidity: the Inner-City Asthma Study. Am J public health. 2004;94:625-32.
90. Kanchongkittiphon W, Gaffin JM, Phipatanakul W. The indoor environment and inner-city childhood asthma. Asian Pacific journal of allergy and immunology/launched by the Allergy Immunology Society of Thailand. 2014;32:103.
91. Sarinho E, Sarinho FW, Sole D. Allergy To Cockroaches: The Need For Standardization Of Extracts For Clinical Practice. J Allergy Clin Immunol. 2014;133:AB241.
92. Takaro TK, Krieger JW, Song L. Effect of environmental interventions to reduce exposure to asthma triggers in homes of low-income children in Seattle. J Expos Sci Environ Epidemiol. 2004;14:S133.
93. D'amato G, Liccardi G, D'amato M, Holgate S. Environmental risk factors and allergic bronchial asthma. Clin Experiment Allergy. 2005 ;35:1113-24.
94. Lee SY, Chang YS, Cho SH. Allergic diseases and air pollution. Asia Pac Allergy. 2013;3:145-54.
95. Singh AB. Pollen and fungal aeroallergens associated with allergy and asthma in India. Glob J Immunol Allerg Dis. 2014;2:19-28.
96. Uddenfeldt M, Janson C, Lampa E, Rask-Andersen A. Sensitization to pets is a major determinant of persistent asthma and new asthma onset in Sweden. Upsala journal of medical sciences. 2013;118:111-21.
97. Sheikh S, Pitts J, Ryan-Wenger N, McCoy K. Ethnic diversity in having pets at home in families with asthma, 2013.
98. Carlsen KC, Roll S, Carlsen KH, Mowinckel P, Wijga AH, Brunekreef B, et al. Does pet ownership in infancy lead to asthma or allergy at school age? Pooled analysis of individual participant data from 11 European birth cohorts. PloS one. 2012;7:e43214.
99. Mészáros D, Burgess J, Walters EH, Johns D, Markos J, Giles G, et al. Domestic airborne pollutants and asthma and respiratory symptoms in middle age. Respirology. 2014;19:411-8.
100. Belanger K, Holford TR, Gent JF, Hill ME, Kezik JM, Leaderer BP. Household levels of nitrogen dioxide and pediatric asthma severity. Epidemiology 2013;24:320.
101. Rogalsky DK, Mendola P, Metts TA, Martin WJ. Estimating the number of low-income Americans exposed to household air pollution from burning solid fuels. Environ Health Perspect. 2014;122:806.
102. Mirabelli MC, Beavers SF, Chatterjee AB. D42 COPD: HOW MANY PHENOTYPES CAN ONE DISEASE HAVE?: Active Asthma, Smoking Status, And The Prevalence Of COPD Among Adults With A History Of Asthma. Am J Respir Crit Care Med. 2014;189:1.
103. Öberg M, Jaakkola MS, Woodward A, Peruga A, Prüss-Ustün A. Worldwide burden of disease from exposure to second-hand smoke: a retrospective analysis of data from 192 countries. The Lancet. 2011 ;377:139-46.
104. Voraphani N, Stern DA, Wright AL, Guerra S, Morgan WJ, Martinez FD. Risk of current asthma among adult smokers with respiratory syncytial virus illnesses in early life. Am J Respir Crit Care Med. 2014;190:392-8.
105. Mukhopadhyay K, Ramasamy R, Mukhopadhyay B, Ghosh S, Sambandam S, Balakrishnan K. Use of ventilation-index in the

development of exposure model for indoor air pollution—A review. Open J Air Pollut. 2014;3:33.
106. Escobedo LE, Champion WM, Li N, Montoya LD. Indoor air quality in Latino homes in Boulder, Colorado. Atmos Environ 2014 ;92:69-75.
107. Derbez M, Berthineau B, Cochet V, Lethrosne M, Pignon C, Riberon J, et al. Indoor air quality and comfort in seven newly built, energy-efficient houses in France. Build Environ. 2014;72:173-87.
108. Ong KH, Lewis RD, Dixit A, MacDonald M, Yang M, Qian Z. Inactivation of dust mites, dust mite allergen, and mold from carpet. J Occup Environ Hyg. 2014;11:519-27.
109. Ramagopal M, Wang Z, Black K, Hernandez M, Stambler AA, Emoekpere OH, et al. Improved exposure characterization with robotic (PIPER) sampling and association with children's respiratory symptoms, asthma and eczema. J Expo Sci Environ Epidemiol. 2014;24:421.
110. Breysse J, Dixon S, Gregory J, Philby M, Jacobs DE, Krieger J. Effect of weatherization combined with community health worker in-home education on asthma control. Am J Public health. 2014;104:e57-64.
111. Li T, Lin G. Examining the role of location-specific associations between ambient air pollutants and adult asthma in the United States. Health Place. 2014;25:26-33.
112. Salvi S, Limaye S. Effects of Air Pollution on Allergy and Asthma. In: Textbook of Allergy for the Clinician. CRC Press; 2014, pp 383-98.
113. Delfino RJ, Wu J, Tjoa T, Gullesserian SK, Nickerson B, Gillen DL. Asthma morbidity and ambient air pollution: effect modification by residential traffic-related air pollution. Epidemiology. 2014;25:48-57.
114. Ahmed T, Pervez A, Mehtab M, Sherwani SK. Assessment of drinking water quality and its potential health impacts in academic institutions of Abbottabad (Pakistan). Desalination Water Treat. 2015;54:1819-28.
115. Penning TM, Breysse PN, Gray K, Howarth M, Yan B. Environmental health research recommendations from the inter-environmental health sciences core center working group on unconventional natural gas drilling operations. Environ health perspect. 2014;122:1155.
116. Masunaga S. Risk Management of Chemical Pollution: Principles from the Japanese Experience. In: Sustainable Living with Environmental Risks Tokyo: Springer; 2014, pp 167-176.
117. Devereux G, Tagiyeva N, Turner SW, Ayres JG, Seaton A, Hudson G, et al. Early-life residential exposure to soil components in rural areas and childhood respiratory health and allergy. Sci Total Environ. 2014;466:338-44.
118. Sing D, Sing CF. Impact of direct soil exposures from airborne dust and geophagy on human health. Int J Environ Res Public Health. 2010 ;7:1205-23.
119. Hough RL. Soil and human health: an epidemiological review. Eur J Soil Sci. 2007;58:1200-12.
120. Nelsen LM, Gater A, Hall R, Coons SJ. Identifying and measuring the core symptoms reported by persons with asthma: a review of the existing qualitative literature and patient-reported outcome measures. InC23. ENVIRONMENTAL AND PSYCHOSOCIAL ASPECTS OF ASTHMA AND COPD 2014 (pp. A4029-A4029). American Thoracic Society.
121. Tovey ER, Stelzer-Braid S, Toelle BG, Willenborg CM, Reddel HK, Garden FL, et al. Asthma Symptoms and Rhinovirus In A Longitudinal Children's Cohort. J Allerg Clin Immunol. 2014;133:AB285.
122. Fattore GL, Santos CA, Barreto ML. Social determinants of childhood asthma symptoms: an ecological study in urban Latin America. J commun health. 2014;39:355-62.
123. Fagan JK, Scheff PA, Hryhorczuk D, Ramakrishnan V, Ross M, Persky V. Prevalence of asthma and other allergic diseases in an adolescent population: association with gender and race. Ann Allerg Asthma Immunol. 2001;86:177-84.
124. Fu JJ, McDonald VM, Gibson PG, Simpson JL. Systemic inflammation in older adults with asthma-COPD overlap syndrome. Allerg Asthma Immunol Res. 2014;6:316-24.
125. Manohar S, Sivanandhan K, Michael A, Selvakumaran R. Studies on allergens causing bronchial asthma and allergic rhinitis. Int J Pharmaceut Sci Res. 2014;5:1416.
126. Killorn KR, Dostaler SM, Olajos-Clow J, Turcotte SE, Minard JP, Holness DL, et al. The development and test re-test reliability of a work-related asthma screening questionnaire. J Asthma. 2015;52:279-88.
127. Guerrero-Medrano L, Gor P, Reyna-Caamaño R, Mejia-Velazquez GM, Santos-Guzman J, Martinez A. Pollution and Lifestyle Causes of Asthma and Allergies Among School Children of Tamaulipas, Mexico in the US–Mexico Border Region. In: Environmental Sustainability Issues in the South Texas–Mexico Border Region. Dordrecht:Springer; 2014, pp 11-23.
128. Vervloet D, Pribil C, Dumur JP, Godard P, Salmeron S, Serrier P, et al. Factors associated with poorly controlled asthma among adults in France. Revue Française d'Allergologie. 2014;54:428-37.
129. Chino H, Takasaki J, Morino E, Sugiyama H. B51 TUBERCULOSIS: DIAGNOSIS: Diagnostic Delay In Endobronchial Tuberculosis With Asthma. Am J Respir Crit Care Med. 2014;189:1.
130. Seeberg J, Pannarunothai S, Padmawati RS, Trisnantoro L, Barua N, Pandav CS. Treatment seeking and health financing in selected poor urban neighbourhoods in India, Indonesia and Thailand. Soc Sci Med. 2014 ;102:49-57.
131. Ringsberg KC, Bjärneman P, Larsson R, Wallström E, Löwhagen O. Diagnosis of asthma in primary health care: a pilot study. J Allergy (Cairo). 2014; 2014: 898965.
132. Sagona JA, Shalat SL, Wang Z, Ramagopal M, Black K, Hernandez M, et al. Evaluation of particle resuspension in young children' s breathing zone using stationary and robotic (PIPER) aerosol samplers. J Aerosol sci 2015;85:30-41.
133. Cane RS, Ranganathan SC, McKenzie SA. What do parents of wheezy children understand by "wheeze"?. Arch dis childhood. 2000;82:327-32.
134. Middleton N, Kolokotroni O, Lamnisos D, Koutrakis P, Yiallouros PK. Prevalence of asthma and respiratory symptoms in 15–17 year-old Greek-Cypriots by proximity of their community of residence to power plants: Cyprus 2006–07. Public health. 2014;128:288-96.
135. Oren E, Rothers J, Stern DA, Halonen M, Wright AL. Cough Duration During Infancy Is Associated With Childhood Asthma. In:B107. UNDERSTANDING DISEASE COMPLEXITY IN ASTHMA. American Thoracic Society; 2014, pp A3842-A3842.
136. Amelink M, Hashimoto S, Spinhoven P, Pasma HR, Sterk PJ, Bel EH, et al. Anxiety, depression and personality traits in severe, prednisone-dependent asthma. Respir med. 2014;108:438-44.
137. Wang L, Gao S, Zhu W, Su J. Risk factors for persistent airflow limitation: Analysis of 306 patients with asthma. Pak J Med Sci. 2014 ;30:1393.
138. Teo SS, Tan NC, Ngoh AS, Swah TS, Chen Z, Tai BC. Smoking behaviour of asthmatic patients in primary care: A cross-sectional study. Proceed Singapore Healthcare. 2014;23:108-17.
139. De Granda-Orive JI, Escobar JA, Gutiérrez T, Albiach JM, Sáez R, Rodero A, et al. Smoking-related attitudes, characteristics, and opinions in a group of young men with asthma. Military Med. 2001;166:959-65.
140. Perkins KA, Briski J, Fonte C, Scott J, Lerman C. Severity of tobacco abstinence symptoms varies by time of day. Nicotine Tob Res. 2009 ;11:84-91.
141. Burney PG, Laitinen LA, Perdrizet S, Huckauf H, Tattersfield AE,

Chinn S, et al. Validity and repeatability of the IUATLD (1984) Bronchial Symptoms Questionnaire: an international comparison. Eur Resp J. 1989 ;2:940-5.
142. Baltussen R, Niessen L. Priority setting of health interventions: the need for multi-criteria decision analysis. Cost eff Resour Alloc. 2006;4:14.
143. Rakotomanana F, Randremanana RV, Rabarijaona LP, Duchemin JB, Ratovonjato J, Ariey F, et al. Determining areas that require indoor insecticide spraying using Multi Criteria Evaluation, a decision-support tool for malaria vector control programmes in the Central Highlands of Madagascar. Int J Health Geographics. 2007;6:2.
144. Arsalan MH. "MONITORING SPATIAL'P ATTERNS OF AIR POLLUTION IN KARACHI• METROPOLIS: A GIS AND REMOTE SENSING PERSPECTIVE." PhD dissertation, UNIVERSITY OF KARACHI KARACHI-PAKISTAiN, 2002.
145. Cromley EK. GIS and disease. Ann Rev public health. 2003;24:7-24.
146. Heinrich J. Influence of indoor factors in dwellings on the development of childhood asthma. Int J Hygiene Environ health. 2011;214:1-25.
147. Mehdi MR, Kim M, Seong JC, Arsalan MH. Spatio-temporal patterns of road traffic noise pollution in Karachi, Pakistan. Environ Int. 2011;37:97-104.
148. Allen DW. GIS tutorial 2: Spatial analysis workbook. Esri Press; 2016 Feb 15.
149. Belton V, Stewart T. Multiple criteria decision analysis: an integrated approach. Springer Science & Business Media; 2002.
150. ESRI. ArcGIS Resource Center: Data classification, 2013.
151. Razzak J, Khan UR, Jalal S. Application of geographical information system (GIS) for mapping road traffic injuries using existing source of data in Karachi, Pakistan--a pilot study. J Pak Med Assoc. 2011;61:640.
152. Ghauri B, Salam M, Mirza MI. An assessment of air quality in Karachi, Pakistan. Environ Monit Assess. 1994;32:37-45.
153. Barletta B, Meinardi S, Simpson IJ, Khwaja HA, Blake DR, Rowland FS. Mixing ratios of volatile organic compounds (VOCs) in the atmosphere of Karachi, Pakistan. Atmos Environ. 2002;36:3429-43.
154. Shabbir Y, Khokhar MF, Shaiganfar R, Wagner T. Spatial variance and assessment of nitrogen dioxide pollution in major cities of Pakistan along N5-Highway. J Environ Sci 2016;43:4-14.
155. Khan IA, Arsalan MH, Siddiqui MF, Hashmi DR, Zeeshan S, Siddiqui BA. Association of Asthma with Carbon Monoxide Concentrations on the Roads of Karachi and Potential Blood Level of Carboxy Haemoglobin. FUUAST J Biol. 2011;1:111.
156. Karim Z, Qureshi BA, Mumtaz M. Geochemical baseline determination and pollution assessment of heavy metals in urban soils of Karachi, Pakistan. Ecol Indicators. 2015;48:358-64.
157. Berend N. Contribution of air pollution to COPD and small airway dysfunction. Respirology. 2016;21:237-44.
158. Zhang JJ, Day D. Urban Air Pollution and Health in Developing Countries. In: Air Pollution and Health Effects. London: Springer; 2015 pp 355-380.
159. Brauer M, Hoek G, Smit HA, De Jongste JC, Gerritsen J, Postma DS, et al. Air pollution and development of asthma, allergy and infections in a birth cohort. Eur Respir J. 2007;29:879-88.
160. Garcia E, Urman R, Berhane K, McConnell R, Gilliland F. Effects of policy-driven hypothetical air pollutant interventions on childhood asthma incidence in southern California. Proceed Natl Acad Sci. 2019 ;116:15883-8.