Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 21, No. 4, p. 42-47, 2022
http://www.innspub.net

INNSPUB

RESEARCH PAPER | OPEN ACCESS

Association between $PM_{2.5}$ and asthma patients hospital visits in Rawalpindi, Pakistan

Javairia Shabnum*, Sheikh Saeed Ahmad, Mehwish Jamil Noor, Javeria Saleem

Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi, Pakistan

Article published on October 10, 2022

Key words: Asthma, Asthma hotspots, Kernel density, $PM_{2.5}$, Satellite remote sensing

Abstract

Exposure to air pollution especially $PM_{2.5}$ has detrimental effect on human health especially on respiratory system. It can cause exacerbations in pre-exisiting asthma and onset new asthma as well. Asthma patient hospital visits in district Rawalpindi, Pakistan were analyzed by using kernel density estimation in ArcGIS 10.2. $PM_{2.5}$ concentrations were recorded gravimetrically as well as OLI/TIRS Land Sat 8 data was processed to reveal the $PM_{2.5}$ concentrations over the study area. Kernel density maps and $PM_{2.5}$ concentration maps were studied to Fig. out the correlation of asthma patient hospital visits and $PM_{2.5}$. Our study revealed the presence of more asthma hotspots with higher $PM_{2.5}$ concentrations exceeding the national air quality standards. Therefore, $PM_{2.5}$ is one of the contributing factors to the asthma prevalence in district Rawalpindi, Pakistan.

***Corresponding Author:** Javairia Shabnum ✉ javairiayounis@gmail.com

Introduction

Unplanned rapid urbanization and industrialization has intensified the concentration of pollution in developing countries. Exposure to air pollution has detrimental effect on human health especially on respiratory systems, lung development and function (Auerbach and Hernandez, 2012; Voynow and Auten, 2015). Asthma is a chronic respiratory disease which is associated with significant rate of mortality and morbidity in developing countries (Sinharoy *et al.*, 2018). Air pollution can cause exacerbations in pre-existing asthma but evidence about new asthma onset has also emerged (Guarnieri and Balmes, 2014). There are various environmental factors that trigger asthma including allergens exposure (dust mites, pollens of various plant species, pets mites, molds), air pollution (Nitrogen dioxide (NO_2), Ozone (O_3), Particulate Matter (PM), and Volatile Organic Compounds (VOC_s). Viral respiratory tract infections and human rhinovirus, food allergens e.g., milk, tobacco smoke are also considered as a triggering factor for asthma (Fang *et al.,* 2016; Gaffin *et al.*, 2014; Pawankar, 2012; RA, 2003). Short term and long term exposure to $PM_{2.5}$ is associated with asthma symptoms and decrement in lung function of both children and adults (Iskandar *et al*, 2012; Mann *et al*, 2010; Meng *et al*, 2010).

Generally air quality monitoring is done by ground monitoring stations which are quite accurate and timely but their spatial coverage is limited as these stations are sparse. Therefore, many researches use satellite remote sensing in assessing the air pollution specially $PM_{2.5}$ (Lijuan, 2020; Mishra *et al*, 2020; Zhao at al., 2018). The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard NASA's Terra and Aqua satellites, Landsat OLI and TIRS, other sensors, such as MISR, OMI, VIIRS, POLDER, and CALIPSO are used for atmospheric aerosols properties. Landsat 8 data with a 30m resolution is ideal for development of precise satellite aerosol optical thickness (AOT). Metrological factors such as temperature, relative humidity and physical characteristics of particles are also important for precise results (Mishra *et al.*, 2020; Wang *et al.*, 2010).

Satellite $PM_{2.5}$ data combined with ground measurements including temperature and relative humidity corrections can be used for disease surveillance.

The present paper attempted to assess the geographical distribution and clusters of asthma in Rawalpindi, Pakistan by using spatial analysis technique Kernal density (KD) in ArcGIS 10.2 software and its association with $PM_{2.5}$ using Landsat 8 data and ground measurements. Other researchers also use kernel density for disease mapping and detection of disease clusters (Murad and Kashoggi, 2020; Rybnikova *et al.*, 2018; kloog *et al.*, 2009). Moreover, correlation between $PM_{2.5}$ and asthma patients hospital visits was also assessed.

Materials and methods

Study area

District Rawalpindi is situated in North-West part of Pakistan. It covers an area of 5286 Sq. km and is administratively divided in to seven tehsils Muree, KotliSattian, Khautta, Kallar Syedan, Gujar Khan, Rawalpindi and Taxila (Fig. 1). Attock is situated in west side of Rawalpindi district whereas Islamabad, Haripur and Abbotabad are in North. In South lies the Chakwal district whereas East is covered by State of Jammu and Kashmir.

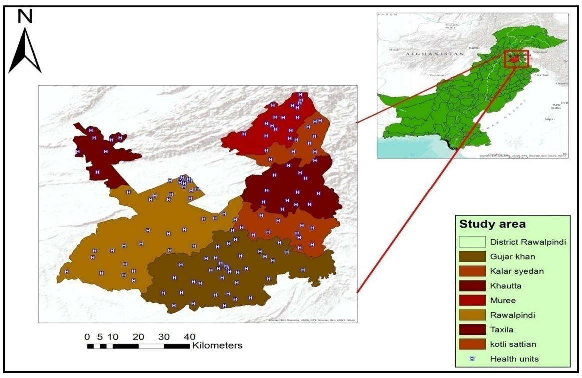

Fig. 1. Study area map.

Data Set

Ground measurements of PM2.5, meteorological parameters and asthma prevalence

$PM_{2.5}$ concentrations (µg/m^3) were recorded at selective locations using gravimetric sampling in both winter and summer season.

Meteorological parameters including temperature (℃) and relative humidity (%) was requested from Metrological department of Pakistan (PMD). Moreover, health facilities data was collected from District health Office Rawalpindi which included the rate of asthma patient hospital visits and locations of health facilities in district.

Landsat 8 data set

An image of 4th december, 2019 was downloaded from Landsat 8 data from https:// earthexplorer.usgs,gov for winter season (December) because of the presence of peaks of asthma cases in this season in district Rawalpindi. The scenes with minimal cloud cover were used.

Pre-processing of data

Radiometric correction was done by converting DN values into top of atmosphere (TOA) reflectance by using Landsat 8 data user's handbook (USGS: Landsat 8 (L8) Data Users Handbook, 2019):

TOA reflectance was calculated by formula

$\rho\lambda' = (M\rho Qcal + A\rho)$

where: ρλ' = TOA planetary reflectance, without correction for the solar angle.

Mρ= Band-specific multiplicative rescaling factor from the metadata (reflectance_mult_band_x, where x is the band number)

Ap= Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)

Qcal = Quantized and calibrated standard product pixel values (DN)

TOA reflectance with a correction for the sun angle is then:

$$\rho\lambda' = \frac{\rho\lambda'}{\cos(\theta sz)} = \frac{\rho\lambda'}{\sin(\theta se)}$$

where: ρλ' = TOA planetary reflectance

θsz = Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (sun_elevation).

θse = Local solar zenith angle. Atmospheric correction was done by using following formula.

Atmospheric Reflectance= TOA Reflectance – Surface Reflectance.

Processing data

Muliband regression analysis was done to relate $PM_{2.5}$ with atmospheric reflectance. It was calculated as by Mishra *et al*, 2021.

Disease mapping

Hotspots for asthma patients were identified using kernel density estimation for December 2019. Maps of kernel density and satellite based $PM_{2.5}$ estimates are created to study the correlation of $PM_{2.5}$ concentrations with asthma prevalence in study area.

Results and discussion

Statistical data related to hospital visits of asthma patients requested from DHO Rawalpindi revealed seasonal patterns in asthma prevalence with highest number of patients during winter months (Nov-Jan). Data was distributed randomly with no spatial autocorrelation. Kernal density estimation revealed maximum hotspots in Rawalpindi tehsil followed by tehsil Gujar Khan for December, 2019. $PM_{2.5}$ concentrations for December, 2019 revealed the higher concentrations in hotspot areas revealing the association of asthma with $PM_{2.5}$ pollution in our study area (Fig. 2).

Sources of higher concentration of $PM_{2.5}$ are due to increased fossil fuel combustion, construction work, smoking, pollen, fungal spores, wood stove burning and roadside traffic (Kim *et al.,* 2013; Kelly *et al.,* 2012). Elevated concentrations in winters in Rawalpindi district (Fig. 2) could be associated with large biomass burning for cooking and heating purpose as confirmed by Zafar *et al.* (2012). Moreover, migration of snow covered northern areas people to the twin cities also increased fossil fuels burning and motorization which leads to the more enhancement of $PM_{2.5}$ in winters.

Ground monitoring of $PM_{2.5}$ concentrations was also done by using high volume air sampler in selective locations for both summer and winter months (2019-2020). Maximum concentration 0.379mg/m^3 was recorded in winter which exceeds the national air quality standards.

$PM_{2.5}$ concentrations were higher in winters as compared to summers. Ground monitoring data also verified the accuracy of satellite data. Our results revealed unhealthy quality of air with $PM_{2.5}$ exceeding the national air quality standards in whole district.

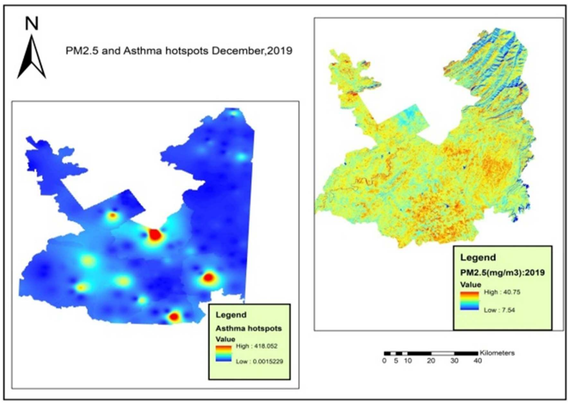

Fig. 2. Asthma hotspots and $PM_{2.5}$ concentrations for Nov, 2019 in Rawalpindi, Pakistan.

Association of exposure to PM with exacerbation of previous asthma as well as onset of new symptoms because of formation of oxidative species is revealed in the previous study (Gavett and Koren, 2001). Globally, 16 million childhood asthma cases are reported annually due to elevated $PM_{2.5}$ exposure. Though the exposure affects all body parts but respiratory system is found to be first line of entry into human body. It penetrates deeply into lungs and intensifies asthma attacks frequency and severity along with other lungs disease (Anenberg *et al.,* 2018). Various studies had revealed the associations of asthma emergency hospital visits and elevated $PM_{2.5}$ concentrations and support our research outcomes. Gorai *et al.* (2014) studied Asthma emergency department visits among New York residents with $PM_{2.5}$ concentration and found positive correlation during 2005-2007. The Canadian Community Health Survey reported hospitals visits of asthmatic patients increased to three fold during cold season when $PM_{2.5}$ reached to elevated level (To *et al.,* 2016). Similarly in our study asthma patients hospital visits were higher in areas with more $PM_{2.5}$ concentrations. Therefore, it is revealed that $PM_{2.5}$ is one of the contributing factors for asthma prevalence in district Rawalpindi.

Conclusion

Asthma morbidity and mortality is increasing in developing countries. Asthma onset and pre-exisiting asthma excerbations are associated with the exposure of $PM_{2.5}$ levels in air. Data related to asthma patients hospital visits in Rawalpindi district revealed seasonal patterns of disease prevalence with highest number of patients recorded in winter seasons. Kernel density estimation disclosed the more number of asthma hotspots in Rawalpindi and Gujar Khan tehsils for December, 2019.

Landsat 8 data was acquired and processed that revealed the elevated $PM_{2.5}$ concentrations in district Rawalpindi. Ground $PM_{2.5}$ concentration measurements also revealed the unhealthy air where $PM_{2.5}$ concentrations exceeded the national air quality standards. Correlation of kernel density estimation and $PM_{2.5}$ concentrations showed the overlay of asthma prevalence with higher $PM_{2.5}$ concentrations in study area. Therefore, $PM_{2.5}$ is concluded as a contributing factor to asthma prevalence in Rawalpindi, Pakistan. There is a further need to Fig. out and manage the sources contributing to $PM_{2.5}$ levels for the effective management of asthma in district Rawalpindi, Pakistan.

References

Auerbach A, Hernandezm L. 2012. The effect of environmental oxidative stress on airway inflammation.Curr Opin Allergy ClinImmunol. **12(2),** 133-9. DOI: 10.1097/ACI.0b013e32835113d6. PMID: 22306553; PMCID: PMC3319111.

Feng M, Yang Z, Pan L, Lai X, Xian M, Huang X, Wong GW. 2016. Associations of Early Life Exposures and Environmental Factors With Asthma Among Children in Rural and Urban Areas of Guangdong, China. CHEST Journal. vol **149(4).** p.1030-1041.

Gaffin JM, Kanchongkittiphon W, Phipatanakul W. 2014.Perinatal and early childhood environmental factors influencing allergic asthma immunopathogenesis. International Journal of Immunopharmacology. Vol **22(1),** p. 21-30.

Gavett SH, Koren HS. 2001.The role of particulate matter in excerbaton of ectopic asthma. International Archieves of Allergy and immunology. Vol **124(1-3),** p.109-12.

Gorai Ak, Tuluri F, Tchounwou PB. 2014. A GIS based approach for assessing the association between air pollution and asthma in New York state, USA. International journal of environmental research and public health, vol **11(5),** p. 4845-4869.

Guarnieri M, Balmes JR. 2014. Outdoor air pollution and asthma. The Lancet, Vol **383(9928),** p.1581-1592.

Iskandar A, Andersen ZJ, Bonnelykke K, Ellermann T, Andersen KK, Bisgaard H. 2012. Coarse and fine particles but not ultrafine particles in urban air trigger hospital admission for asthma in children. Thorax, vol **67,** p.252-57.

Kelly JF, Fussell CF. 2012. Size, source and chemical composition as determinants of toxicity attributable to ambient particulate matter. Atmosperic Environment. Vol **60.** p. 504-526.

Kim k, Jahan AS, Kabir E. 2013. A review on human health prespective of air pollution with respect to allergies and asthma. Environmental International. Vol **59.** p.41-52.

Kloog I, Haim A, Portnov AB. 2009. Using kernel density function as an urban analysis tool: Investigating the association between nightlight exposure and the incidence of breast cancer in Haifa, IsraelComputers, Environment and Urban Systems. vol **33(1),** P. 55-63.

Lijuan Y. 2020. A novel approach of Landsat 8 imagery to predict PM 2.5 concentrations in a south-eastern coastal city of China. IOP Conference Series: Earth and Environmental Science. Vol **619.**

Mann JK, Balmes JR, Bruckner TA. 2010.Short-term effects of air pollution on wheeze in asthmatic children in Fresno, California. Environ Health Perspect, vol **118,** P. 1497-502.

Meng Y-Y, Rull RP, Wilhelm M, Lombardi C, Balmes J, Ritz B. 2010. Outdoor air pollution and uncontrolled asthma in the San Joaquin Valley, California. J. of Epidemiol Community Health, vol **64,** p.142-47.

Mishra KR, Agarwal A, Shukla A. 2021. Predicting Ground Level $PM_{2.5}$ Concentration Over Delhi Using Landsat 8 Satellite Data. International Journal of Remote Sensing, vol **42(3),** p. 827-838, DOI: 10.1080/2150704X.2020.1832279

Murad A, Khashoggi BF. 2020. Using GIS for Disease Mapping and Clustering in Jeddah, Saudi Arabia. ISPRS International Journal of Geo-Information, vol **9(5),** p.328. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijgi9050328

Pawankar R, Canonica GW, Holgate ST, Lockey RF. 2012. Allergic diseases and asthma: a major global health concern. Current Opinion in Allergy and Clinical Immunology.vol **12(1),** p. 39-41.

RA E. 2003. How environmental exposures influence the development and exacerbation of asthma. Pediatrics. Vol **112,** P. 233-9.

Rybnikova N, Richard G, Stevens DI. Samociuk HG, Portnov AB. 2018. Kernel density analysis reveals a halo pattern of breast cancer incidence in Connecticut, Spatial and Spatio-temporal Epidemiology. Vol **26,** p. 143-151,ISSN 1877-5845, https://doi.org/10.1016/j.sste.2018.06.003.

Sinharoy A, Mitra S, Mondal P. 2018. Socioeconomic and Environmental Predictors of Asthma-Related Mortality. J Environ Public Health. Vol **24,** doi: 10.1155/2018/9389570.
PMID: 29853926; PMCID: PMC5941796.

To T, Stanojevic S, Moores G, Gershon AS, Bateman ED, Cruz AA, Boulet LP. 2012. Global asthma prevalence in adults: findings from the cross-sectional world health survey. BMC Public Health. Vol **12(1),** p.1.

Voynow JA, Auten R. 2015.Environmental Pollution and the Developing Lung. Clinical pulmonary medicine **22(4),** 177-184.
https://doi.org/10.1097/ cpm.0000000000000095

Wang Z, Chen L, Tao J, Zhang Y, Su L. 2010. Satellite-based estimation of regional particulate matter (PM) in Beijing using vertical-and-RH correcting method.Remote sensing of Environment. Vol **114(1),** p. 50-63.
DOI: 10.1016/j. rse.2009.08.009

Zafar L, Ahmad SS, Syed WAA, Ali SS. 2012. Temporal variations in nitrogen dioxide concentration due to vehicular emissions in Islamabad capital territory (ICT) & Rawalpindi. Science International Lahore. Vol **24,** p. 265-268.

Zhao Y, Huang B, Marinoni A, Gamba P. 2018.High spatiotemporal resolution PM2.5 concentration estimation with satellite and ground observations: A case study in New York City. IEEE International Conference on Environmental Engineering (EE), p. 1-5.