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Air Pollution Assessment in Fuel Stations and its Impact on Workers' Health: a Case Study from Jeddah, KSA

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ABSTRACT

Variations in concentrations of PM10, PM2.5, BTEX (benzene, toluene and xylene) carbon monoxide (CO), nitrogen dioxide (NO_2), were monitored at 15 petroleum-filling stations in the metropolitan city of Jeddah, Saudi Arabia. The concentrations of benzene, toluene, xylene, NO_2, CO, $PM_{2.5}$ and PM_{10} concentrations were 3114, 2143 ,4326, 36, 2152, 344 and 710 µg m^{-3}, respectively. Theses concentrations are higher than ambient air standards, indicating poor air quality at pump stations. The personal exposure to benzene, toluene and xylene (BTEX) were determined as well as the pulmonary functions. Different Pulmonary functions were significantly decreased in the present study compared to the control group. These findings suggest a significant pulmonary impairment. Moreover, this impairment in the lung function, mainly on lower airways with restrictive, pattern of disease was associated with a dose effect response to the duration of the exposure to petrol fumes, diesel exhaust and VOCs. There were strong correlation ($P \leq 0.01$) between gaseous pollutants and lung functions and PM. Moreover, correlation was significant ($p < 0.05$) between benzene concentration and urinary *t,t*-MA in the study group

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INTRODUCTION

With urbanization and rapid increasing number of automobiles in most of the towns and cities, there is an increase in the air pollution. Numerous epidemiological studies have documented decrements in pulmonary function and various other health problems associated with long-term air pollution exposure [1]. There is also a convincing evidence for an association between air pollution and cardiovascular disease [2]. Health effects of occupational exposure to petroleum vapors and air pollution from vehicular sources is relatively unexplored among petrol filling workers [3]. It is widely accepted that transport emitted air pollution has an adverse effect on health outcomes such as mortality, morbidity, and hospital admissions. In addition, the economic costs of this can be great [4].

Air pollution from vehicles is an inescapable part of the urban life throughout the world. A long-term exposure to the air pollutants leads to deleterious effects on the respiratory functions. Air pollutants and chemicals like benzene, lead and carbon monoxide can cause adverse health effects by interacting with molecules, which are crucial for the biochemical or physiological processes of the human body. The rapidly multiplying number of automobiles in most cities is causing a corresponding increase in air pollution. Also, the failure to use personal protect Also, the failure to use personal protective equipment poses a great risk for the petrol-filling workers [5].

Petrol, also called gasoline is a complex combination of hydrocarbons. About 95% of components in petrol vapor are aliphatic and acyclic compounds and less than 2% is aromatics. The benzene content of petrol has typically been in range 1–5%. Typical 8-hour benzene exposure concentrations in distribution and retail operations average less than 1 ppm, although exposures can reach 2–3 ppm for shorter periods [6]. Saudi Arabia still does not have an air quality standard for benzene. Petrol filling station is a place where workers are exposed

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to both petroleum vapors and the vehicular exhaust [7]. The combined effects of the two may result in accelerated decline in lung functions [8]. Traffic emissions result in small–scale spatial variations and affect urban and regional background air pollution concentrations. Short–term and long–term exposure to traffic–related air pollution may shorten life expectancy [9]. Traffic is a major emission source of particles especially in urban areas [10- 12].

In KSA, petrol-filling workers are employed rather than self-serviced, increasing the opportunity for exposure. Long-term exposure to petrol vapor has shown to affect the different physiological systems in the body. Cohort studies suggest that exposure to air pollution is associated with respiratory and cardiovascular diseases and lung cancer [13 – 15]. WHO [16] stated that prolonged exposure through inhalation and handling might therefore constitute a significant occupational hazard at such distribution centers. Consequently, it is important to screen air in the work environment for the presence of aromatic hydrocarbons as well as other pollutants such as CO, NO_x and PM [17].

The aim of the study were to quantify ambient concentrations of particulate matters, BETX and to evaluate biomarkers of exposure to gasoline in petrol station workers by a combined approach of environmental and biological monitoring, and to assess the extent of altered pulmonary functions in petrol-pump workers who were exposed to petrol and diesel fumes and to study the effect on the duration of the exposure to the petrol/diesel fumes.

MATERIALS AND METHODS

The present study was conducted in various petrol filling stations of Jeddah City with due permission of the managers. The ethical committee clearance and an informed consent of the subjects were considered [1].

The study group consists of 150 males in the age group of 30 - 50 years old, who were working in various petrol filling stations as petrol filling attendants, 8 hours per day for more than 2 years in Jeddah. The control group consisted of 150 males of same age group, who were not exposed to petroleum vapor.

All workers and the control group chosen in the study had no history of allergic disorders, respiratory disorders like asthma, or any systemic disease and no history of smoking, chewing tobacco, intake of alcohol and no history of previous exposure to petroleum vapor [18].

2.1 Sampling of Particulate Matter (PM10 and PM2.5):

Particulate matter concentrations (PM10, PM2.5) were measured with one minute average by an optical scattering spectrometer (EDM-180D, Grimm Aerosol, Germany). The aerosol sampling was performed at 5 m height above the ground. A routine check on the instrument was performed every two weeks [18, 20].

2.2 Morphology of PM:

The morphology of particulate matter was investigated by the scanning electron scanning microscopy (SEM) (JSM-35CF).

2.3 Sampling and analysis for benzene (C6H6), toluene (C6H5 CH3) and xylene (C6H4 (CH3)2):

Samples were collected on the basis of active sorption on charcoal tubes. Tubes each filled with one gram of activated charcoal were fitted into a Volatile Organic Compounds (VOCs: compounds having high vapor pressure at ambient room temperature and low boiling point, generally 50–250^{0}C) monitor. Low flow organic vapor samplers were placed within 1 - 2 meter of petrol/diesel pump machines. The instruments were elevated to a height of 1.5 m, the breathing zone of the dispensing crew. Sampling was conducted for one hour during peak filling times according to [17].

2.4 Sampling of *carbon monoxide and nitrogen dioxide:*

Ambient CO and NOx concentrations were measured simultaneously with chemiluminescence NO - NO2 – NOx analyzer Model 42*i* and 48*i* CO Analyzer (Thermo Scientific, USA), respectively, in the range of 0–50 ppb to 0–100 ppm internal Zero/span Assembly with a detection limit of < 0.4 ppb [21].

There were two types of calibration; manual one through gas cylinders of known pollutants concentration and autocalibration through permeation tubes (zero air is being generated *in situ*). The calibration was done manually once a month to ensure accuracy and to double check on the autocalibration [22 – 24] for quality control.

2.4 Pulmonary Functions and Biomarkers:

The pulmonary function tests were performed at twenty filling stations, distributed along transict in Jeddah city, by using a Medspiror (Recorders and Medicare System, Chandigarh). It is a computerized spirometer which is designed to be used with electromechanical pneumatic. The testing procedures are quite simple and non-invasive and are harmless to the workers. All the tests were carried out at the same time of the day, between

7.30 AM to 11.00 AM to avoid possible diurnal variations. Tests were performed using the acceptability standards outlined by the American Thoracic Society (ATS) with workers in a standing position and wearing nose clips. The workers were asked to breathe forcefully following deep inspiration into the mouthpiece attached to the pneumatachometer. Expiration was maintained for a minimum period of 3–4 seconds, 3 to 4 trails of maximal inspiratory and expiratory efforts were made and the highest reading was taken for statistical analysis. The parameters studied were, Forced Vital Capacity (FVC), Forced Expiratory Volume in first second (FEV1), FEV1/FVC (FEV1%), Peak Expiratory Flow Rate (PEFR), and Maximum Voluntary Ventilation (MVV) [1].

Biological monitoring for benzene exposure was performed by measuring *trans,trans* muconic acid (*t,t*-MA) End-shift urine samples (1 ml) were adjusted to pH 7–9 with phosphate buffer pH 7.4 passed through the preconditioned Q-SAX anion-exchange cartridge and the (*t,t*-MA) is extracted with 10% acetic acid and later analysed by HPLC (UFLC, Shimadzu) [19].

2.6. Statistical Analysis:

One-Way ANOVA was applied to log-transformed data to ensure normal distribution using STAGRAPICS Statistical package 5 (Sunderland, UK). Mean and Standard Deviation, Independent. Significant differences between means were tested by LSD ($p < 0.05$). Correlation coefficient analysis was applied to investigate the relationship between different pollutants and pulmonary functions.

3. Results

The concentrations of benzene, toluene and xylene are presented in Figure 1.Their concentrations were 3114, 2143 and 4326 µg m^{-3}, respectively.

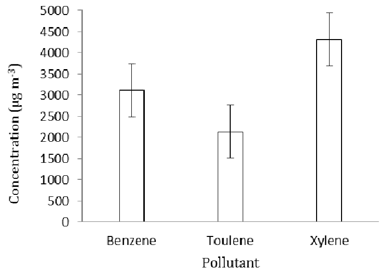

Fig. 1: Concentrations of BTEX in petrol filling stations.

Concentrations of nitrogen Oxide (NO_x), carbon monoxide (CO), $PM_{2.5}$ and PM10 in the study area were 36, 2152, 344 and 710 µg m-3, respectively (Fig. 2).

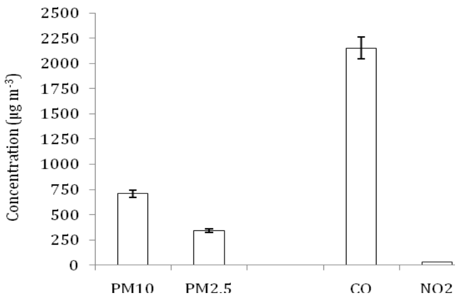

Fig. 2: PM, CO and NO_2 concentrations in petrol filling stations.

SEM micrographs represent the morphology particulate matter. They are irregular in shape (Fig. 3). PM2.5. are more or less spherical, while PM10 are elongated particles

Table 1 shows the difference in different Pulmonary functions; FVC, FEV1, PEFR, MVV and FEV1%, between different groups. FVC, FEV1, PEFR and MVV decreased by 44, 32, 23, 18% respectively ($P \leq 0.01$) when compared with control group. Moreover, FEV1% was found to decrease but it was not statistically significant ($P > 0.05$).

The mean *t,t*-MA found among study and controls were 615.11 and 211.88 µg g^{-1} creatinine, respectively (Fig 3).

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Fig. 3: SE micrographs of PM (X 1750).

Table 1: Different pulmonary function parameters between study and control groups (n = 150). Means not followed by the same letter are significantly different from each other at P≤ 0.05. Each value is a mean + 1 SD; *, ** and *** are significant at P _ 0.05, 0.01 < P < 0.05 and P _ 0.01, respectively.

Lung function	Control group	Study group
FVC (L)	$4.02^{b}\pm0.80$	$2.24^{a***}\pm0.51$
FEV1 (L)	$3.61^{b}\pm0.27$	$2.47^{a***}\pm0.55$
PEFR (L/sec)	$9.25^{b}\pm1.34$	$7.15^{a**}\pm0.74$
MVV (L/min)	$139.16^{b}\pm18.43$	$114^{a*}\pm10.17$
FEV1%	88.07±10.11	85.79±9.37

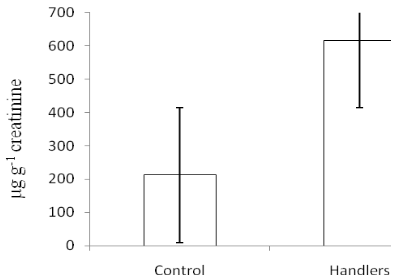

Fig. 4: Mean levels of urinary t,t-MA among Petrol handlers and controls.

Correlation coefficients (r) between different gaseous pollutants and lung functions are illustrated in Tab. 2. There were strong negative coefficient ($P \leq 0.01$) between gaseous pollutants and lung functions (ranged from - 0.17 to - 0.77). Nevertheless, there was strong positive correlation coefficient ($P \leq 0.01$) between gaseous pollutants and PM (0.19 – 0.55). Moreover, correlation was significant ($p < 0.05$) between personal air benzene concentration and urinary *t,t*-MA in the study group (data not shown).

Table 2: Relationship between PM, BETX, NO_x and different pulmonary functions.

	$PM_{2.5}$	PM_{10}	NO_x	benzene	toluene	xylene	FVC	FEV1	PFER	MVV	REV%	t,t-MA
PM2.5	-	0.34	0.21	0.36	0.41	0.35	-0.67	-0.45	-0.85	-0.45	-0.67	0.06
PM10		-	0.36	0.24	0.44	0.28	-0.55	-0.62	-0.45	-0.37	-0.51	0.04
NOx			-	0.23	0.19	0.36	-0.45	-.038	-0.27	-0.31	-0.19	0.11
benzene				-	0.47	0.55	-0.17	-0.21	-0.37	-0.26	-0.38	0.56
toluene					-	0.47	-0.37	-0.33	-0.25	-0.37	-0.31	0.34
xylene						-	-0.49	-0.45	-0.56	-0.47	-0.46	0.42
FVC							-	0.77	0.56	0.56	0.67	0.03
FEV1								-	0.44	0.61	0.56	0.06
PEFR									-	0.59	0.47	0.02
MVV										-	0.45	0.01
FEV1%											-	0.01
t,t-MA												-

Discussion:

Air pollution from vehicles is an inescapable part of the urban life throughout the world [20 -21]. A long term exposure to the air pollutants such as benzene and carbon monoxide leads to deleterious health. They are crucial for the biochemical or physiological processes [1, 18]. Recently, Vlachokostas *et al*. [24] reported that citizens live, work, commute, or visit traffic intensive spaces and are exposed to high levels of chemical health stressors such as xylene, toluene, NO_x, which can pose human health risks.

However, urban conurbations worldwide present monitoring “shortage” - due to economical and/or practical constraints - for toxic stressors such as xylene isomers, which can pose human health risks. This “shortage” may be covered by the establishment of associations between rarely monitored substances such as xylene and more frequently monitored (i.e. benzene) or usually monitored (i.e. CO).

Generally, the concentrations of CO measured in our study, were below the EPA eight-hour CO standard of 10,000 µg m^{-3} [25]. However, CO concentrations exceed the eight-hour CO standard (2000 µg m^{-3}) [26]. The affinity of haemoglobin for CO is much higher than that for oxygen (200 time), and this hampers the distribution of oxygen in the body [16, 27].

NO_x, does not exceed the EPA 24-hour NO_x standard of 80 µg m^{-3} and this support our earlier findings [21].

More than half of the study cases (≈ 85) have higher *t*,*t*-MA values than the biological exposure index of the American Conference of Government Industrial Hygienist (ACGIH) which is 378.98 µg g^{-1} and this represent a threat to health of benzene-exposed workers. The higher *t*,*t*-MA contents recorded in the present study could not be ascribed solely to due to a higher concentration of benzene in the occupational environment, it could be due to bad habits such as smoking or bad dietary habits such as consuming canned food. However lower levels of this biomarker in control group could give some confidence that the gasoline handlers are at risk due to higher levels of benzene in gasoline filling stations

It is well known that PM in air are partially associated with traffic movement and tail-pipe emissions. They affect lung capacity and could even trigger respiratory problems such as asthma

Physical and chemical characteristics as well as concentration of surfactant are known to be altered by gaseous pollutants that could lead to the early closure of the terminal bronchioles. Such closure would affect FEV1 [28]. Air pollutants can easily diffuse deeply in lungs resulting in lung damage [24, 29, 30]. Smoking could exacerbate such effects, although we did not include smoking in this study and many workers are heavily smokers. This warrants further investigation in the future.

Chronic exposure to hydrocarbons would lead to chronic inflammation of respiratory system, leading eventually, to a substantial decrease in lung functions in the form of restrictive pattern. Reduced mechanical properties of breathing were attributed to exposure to benzene, toluene and xylene in the vapors of petrol. Moreover, exposure to particulate matter cause the same symptoms as they carry these hydrocarbons on their surfaces and stay for long time in the air, especially here in Jeddah where air movement is low and no rain for prolonged periods of the year. Exposure to particulate matter combined with exposure to an irritant gas such as NO_x, results in greater damage to the lung than when exposed to either substance individually. Our results showed adverse effects of petrol/diesel fumes on pulmonary functions among workers. This confers that the cardio-respiratory system is the major target of particulate matter impacts [12].

Since there is no available EU legislation for xylene limit values, other existing recommended ambient guidelines should be considered for comparison purposes.

In conclusion, the results show that petrol filling workers are generally exposed to lower levels of NO_x, but are exposed to higher levels of PM. Control strategies should be adopted to reduce the vapor concentration in the ambient air, to protect not only petrol filling workers, but also people who are living nearby. Moreover, Decline in airflow obstruction in subjects exposed to high PM concentrations can be attributed to the fibrogenic response and associated airway wall remodeling. The study suggests the intervention of policy makers and stake holders to take necessary steps to reduce the emissions of PM, VOCs, and NOx concentrations, which can lead to serious respiratory health concerns in residents. Based on these findings, the *t*,*t*-MA can be used as a biomarker for benzene exposure.

Further long-term perspective studies of petrol filling workers will help in getting a comprehensive picture of long term effects.

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REFERENCES

[1] Aprajita, N., N.K. Parwar, R.S. Sharma, 2011. A Study on the Lung Function Tests in Petrol-Pump Workers. *Journal of Clinical and Diagnostic Research,* 5(5): 1046-1050

[2] Novikova, L.V., N.Y.U. Stepanova, V.Z. Latypova, 2014. The Human Health Risk Assessment from Contaminated Air in the Oil-Producing Areas (On the Example of Novoshehminsky Region of the Republic of Tatarstan). Adv. Environ. Biol., 8(13): 109-111

[3] Spengler, J., J. Lwebuga-Mukasa, J. Vallarino, S. Melly, S. Chillrud, J. Baker, Minegishi T. Air toxics exposure from vehicle emissions at a U.S. border crossing: Buffalo Peace Bridge Study. *Res Rep Health Eff Ins*., 158: 125-132.

[4] Kingham, S., I. Ian Longley, J. Salmond, W. Woodrow, K. Kreepa Shrestha, 2013. Variations in exposure to traffic pollution while travelling by different modes in a low density, less congested city. *Environmental Pollution* 181: 211 – 218.

[5] Salvi, S., A. Blomberg, M. Salar, B. Rudell, F. Kelly, T. Sandstrom, 1999. Acute inflammatory responses in the airways and peripheral blood after a short-term exposure to diesel exhaust in healthy human volunteers. *Am J Respir Crit Care Med*; 159: 702-709.

[6] Onat, B., B. Stakeeva, 2013. Personal exposure of commuters in public transport to PM2.5 and fine particle counts. *Atmospheric Pollution Research*, 4: 329-335. http://doi: 10.5094/APR.2013.033
[7] USEPA, (United States Environmental Protection Agency), 2007. Office of Transportation and Air Quality. National idling reduction campaign.
[8] Ahmed, F.E., 2001. Toxicology and human health effects following exposure to oxygenated or reformulated gasoline. *Toxicol Lett*, 123: 89-113.
[9] Hoek, G., B. Brunekreef, S. Goldbohm, P. Fischer, P.A. van den Brandt, 2002. Association between mortality and indicators of traffic–related air pollution in the Netherlands: a cohort study. *Lancet,* 360: 1203– 1209.
[10] Weijers, E.P., A.Y. Khlystov, G.P.A. Kos, J.W. Erisman, 2004. Variability of particulate matter concentrations along roads and motorways determined by a moving measurement unit. *Atmospheric Environment, 38: 2993–3002.*
[11] Gertler, A.W., 2005. Diesel vs. gasoline emissions: does PM from diesel or gasoline vehicles dominate in the US?. *Atmospheric Environment*, 39: 2349–2355.
[12] Ede, P.N., Y. Pere, 2014. Lung Function of Traffic Wardens Linked to airborne Particulates in Nigeria. *Life Sci J.,* 11(9):1-8.
[13] Dockery, D.W., C.A. Pope, X.P. Xu, J.D. Spengler, J.H. Ware, M.E. Fay, B.G. Ferris, F.E. Speizer, 1993. An association between air–pollution and mortality in six U.S. cities. *New England Journal of Medicine* 329: 1753–1759.
[14] Pope, C.A., M.J. Thun, M.M. Namboodiri, D.W. Dockery, J.S. Evans, F.E. Speizer, C.W. Heath, 1995. Particulate air–pollution as a predictor of mortality in a prospective–study of us adults. *American J. Respiratory and Critical Care Medicine*, 151: 669–674.
[15] WHO, 2000. Benzene, Air Quality Guidelines (Copenhagen, Denmark: WHO Regional Office for Europe).
[16] Sehgal, M., R. Suresh, V.P. Sharma, S.K. Gautam, 2011. Variations in air quality at filling stations, Delhi, India. *Int. J. Environmental Studies,* 68 (6): 845-849. http://dx.doi.org/10.1080/00207233.2012.620320
[17] Begum, S., M.B. Rathna, 2012. Pulmonary function tests in petrol filling workers in mysore city. *Pak. J. Physiolo,* 8: 12 – 14.
[18] Hussein, T., M.A. Alghamdi, M. Khoder, A.S. Abdel Maksoud, H. Al-Jeelani, M.K. Goknil, Shabbaj II 2014. Particulate Matter and Number Concentrations of Particles Larger than 0.25 μm in the Urban Atmosphere of Jeddah, Saudi Arabia. *Aerosol and Air Quality Research,* 14: 1383–1391. http://doi: 10.4209/aaqr.2014.02.0027
[19] Raghavan, S., K. Basavaiah, 2005. Biological monitoring among benzene-exposed workers in Bangalore city, India. *Biomarkers*, 10(5): 336 - 341. http://informahealthcare.com/doi/full/10.1080/13547500500274206
[20] Hassan, I.A., J. Basahi, 2013. Assessing roadside conditions and vehicular emissions using roadside lettuce plants. *Polish J. Environ. Studies,* 22(2): 75-81.
[21] Gomez-Perales, J.E., R.N. Colvile, M.J. Nieuwenhuijsen, A. Fernandez-Bremauntz, V.J. Gutierrez-Avedoy, V.H. Paramo-Figueroa, S. Blanco-Jimenez, E. Bueno- Lopez, F. Mandujano, R. Bernabe-Cabanillas, E. Ortiz-Segovia, 2004Commuters' exposure to PM2.5, CO, and benzene in public transport in the metropolitan area of Mexico City. *Atmospheric Environment* 38: 1219 – 1229
[22] Lindén, J., S. Thorsson, I. Eliasson, 2008. Carbon monoxide in Ouagadougou, Burkina Faso Comparison between urban background, roadside and in-traffic measurements. *Water, Air, & Soil Pollution,* 188: 345-353.
[23] Hassan, I.A., J.M Basahi,. I. Ismail, T. Habbebullah, 2013. Spatial Distribution and Temporal Variation in Ambient Ozone and Its Associated NOx in the Atmosphere of Jeddah City, Saudi Arabia *Aerosol and Air Quality,* 13: 1712 – 172.
[24] Vlachokostas, Ch., A. Michailidou, D. Spyridi, N. Moussiopoulos, 2013. Bridging the gap between traffic generated health stressors in urban areas: Predicting xylene levels in EU cities. *Environmental Pollution,* 180 : 251 – 258. http://dx.doi.org/10.1016/j.envpol.2013.05.035.
[25] EPA, 2011. Report on air quality standards. Available online at: http://www.epa.gov/air/criteria.html.
[26] CPCB (Central Pollution Control Board), 2011. Available online at: http://cpcb.nic.in/National_Ambient_Air_Quality_Standards.php.
[27] Longo, L.D., 1997. The biological effects of carbon monoxide on pregnant woman fetus and newborn infant. *American J. Obstetrics and Gynaecology*, 129: 69–103.
[28] Souza, M.B., P.H. Saldiva, C.A. Pope, V.L. Capelozzi, 1998. Respiratory changes due to long term exposures to urban levels of air pollution. *Chest*, 113: 1312–1318.
[29] Gamble, J., W. Jones, S. Minshall, 1987. Epidemiological- Environmental study of Diesel Bus Garage workers: Acute effects of NO2 and respirable particulate on the respiratory system. *Environ Research,* 42: 201–214.
[30] Kesavachandran, C., B.S. Pangtey, V. Bihari, M. Fareed, M.K. Pathak, A.K. Srivastava, N. Mathur, 2013. Particulate matter concentration in ambient air and its effects on lung functions among residents in the National Capital Region, India. *Environ Monit Assess,* **185**(2): 1265-72.