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Pollution in Lucknow City and its health implication on exposed vendors, drivers and traffic policemen

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Abstract In this pilot study, an exposure–response assessment (aged 16 to 60 years, n=1,012) was carried out related to eye problems due to vehicular fumes during the winter of 2003. Inhalable particles <PM_{10} and Pb level were monitored at 12 locations of Lucknow using a Respirable Dust Sampler and EPM 2000 filter. The range of PM_{10} particles varied from 144 to 305, 211–366 and 141–242 μg/m^3 while Pb levels were 0.02–0.93, 0.06–0.90 and 0.07–0.77 μg/m^3 during 2002, 2003 and 2004, respectively. The concentrations of PM_{10} exceeded alarmingly the prescribed standards by a factor of 1.3–3.2. A health survey demonstrated that symptoms were developed such as burning of eyes (in 20 % of drivers, 74.07 % of vendors and 77.47 % of traffic policemen), eye watering (in 51.45 % of drivers, 44 % of vendors and 72.77 % of traffic policemen), constant irritation and redness (in 33.49 % of drivers, 21.29 % of vendors and 26.12 % of traffic policemen) and impaired vision (in 25.01 % of drivers, 20.37 % of vendors and 23.5 % of traffic policemen). The main finding was the prevalence of symptoms of the eyes among the population exposed to automobile fumes.

Keywords Air pollution · Health effects · Vendors · Drivers · Traffic policemen

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Introduction

Lucknow (26°52′N latitude, 80°56′E longitude, 128 m above sea level) is the capital of India's largest state, Uttar Pradesh, spread over an area of 310 km^2 and located at the bank of the river Gomati. It is famous for its historical, splendid buildings and monuments. Population is about 3,681,416. Its total vehicular population (trucks, buses, taxis, 2/4-stroke motorcycles and three-wheeler tempos or auto rickshaws) was 614,794 during 2002–2003 and increased to 679,347 during 2003–2004, registering an increase of 10.5 %. Like most of the Indian cities, Lucknow also developed haphazardly and awkwardly. The carrying capacity of the narrow, congested roads is very low. With the growth of the Indian economy, more and more petrol and diesel-fuelled small- and medium-size cars are plying. The daily introduction of new vehicles, a continuation of old and fuel-inefficient vehicles, aggravate the "canyon effect" among the urban population. The gasoline engine exhaust consists of particulate matter, CO, HC, NO_x, SO_2, aldehydes, while the diesel vehicles produce low concentrations of CO, unburnt HC and polycyclic aromatic hydrocarbons but produce higher concentrations of NO_x. Diesel exhaust also consists of finer particles, aldehydes as well as odour-producing compounds. The particles emitted by motor vehicles are mostly black carbon soot which varies in size from 0.02 to 0.13 μm and 0.04 to 0.06 μm for diesel and petrol engines, respectively (Ristovski et al. 1998; Morawska et al. 2002). The automobile is the major identified source of air pollution in Lucknow (Kisku et al. 2003), like in other urban areas (Baumbach et al. 1995; Derwent et al.. 1995). Studies confirmed the positive correlation between particulate air pollution and adverse health effects, including acute and chronic respiratory diseases in children and adults (Forbes et al. 2009;

Samet et al. 2000; Qian et al. 2004), and the deaths of 4,703 persons occurred due to the fog in London during December 1952 (Logan 1953). Although WHO has evaluated the risks posed to human health by air pollution way back in 1950, WHO formulated the guideline values for limiting air pollutant concentrations in 1972.

In the present investigation, a random health survey of 1,012 subjects exposed to air pollutants was carried out in urban areas of Lucknow after receiving the complaints from the Association of Retired Citizens to assess the magnitude of the cumulative adverse impact of pollutants (PM_{10} and lead) on community health with special reference to ocular problems, especially on highly exposed groups of vendors, drivers and traffic policemen.

Materials and methods

Monitoring locations and sampling procedure

Twelve sensitive locations representing residential, commercial cum traffic and industrial activities were selected for air quality monitoring. A Respirable Dust Sampler (model APM 460, Envirotech, New Delhi) was continuously used for 24 h for sampling of PM_{10}. The frequency of sampling was 2 days in a week for 2 months during the winter seasons of 2003–2004 and 2005. Particles >10 μm in size were separated due to centrifugal force and deposited in a cyclone cap attached to a cyclotron. The fine particles <PM_{10} collected on the EPM 2000 filter, 8×10 in. (Whatman), previously conditioned at 70–80 °C were determined gravimetrically (Bureau of Indian Standards, Govt. of India 2006).

Lead analysis in PM_{10}

The respirable dust deposited on the EPM 2000 filter was processed for estimation of Pb. Three circles of equal area (30.2 cm^2) were punched from the sampled region of the filter paper. The circles were cut into small pieces and soaked overnight in a digestion mixture of perchloric acid and nitric acid (1v $HClO_4$:5v HNO_3) and then heated on a hot plate at 100–110 °C to near dryness. The flasks were allowed to cool to room temperature. The flasks were rinsed with 1 N HNO_3 and filtered through Whatman filter. The filtrate was made up to 10 ml with 1 N HNO_3 (Chelani et al. 2001) and quantitatively analysed for Pb in a flameless atomic absorption spectrophotometer (Varian Spectra AA250 Plus, Australia) equipped with graphite tube automizer and with deuterium background correction. A hollow cathode lamp (Varian) for Pb was used at a working current of 5 mA with 283.3 nm spectral line and 0.5 nm band widths. Similarly, an unexposed EPM-2000 filter was processed which was referred to as blank, and these values were subtracted from sample results.

Health effects monitoring

The pilot health survey for exposure–response assessment was carried out during the winter of 2003 for monitoring of health effects, conducted on a modified questionnaire of WHO with special emphasis on ocular problems due to exposure to pollutants from vehicular exhaust or emissions. The factors affecting human health due to air pollution depend upon: nature and concentration of pollutants, duration of exposure, physical state of health and routine exercise of the receptor, age group of the receptor and socio-economic status of the receptor. We identified randomly 1,012 subjects (aged 16 to 60 years, n=1,012) comprising street vendors, drivers and traffic policemen. These professions are mainly engaged in by male persons in India. The population exposed to the auto exhaust emission for long duration at major crossings/high traffic congestion zones were taken for experimental studies according to stratification and zone assessment for environmental studies. The urban residents of colonies/rural population adjoining the city were taken as control subjects. Through face-to-face interview with the subjects, symptoms of eye watering, redness, burning and impaired vision were studied. Interviewers have been trained prior to the study about the ocular symptoms, classification and documentation of symptoms. Personal interviews were recorded every fortnight, and the test on format to assess the individual variations like chewing of tobacco/betel nut, occupation and level of education, medical history and general complaints during and after exposure to auto exhaust emissions was also recorded. Ten traffic areas were surveyed consisting of high- and medium-polluted areas, and they were compared with subjects of the low-polluted zone which served as control. The primary selection of the occupants was likely to be similar in terms of geographical area, physical demand and wages, etc. Analogous health studies have also been carried out in Switzerland (Zemp et al. 1999), China (Mead and Brajer 2006), Taiwan (Yang et al. 1997) and India (Jayanthi and Krishnamoorthy 2006).

Statistics

Data were analysed using two-factor analysis of variance (ANOVA), and groups within factors were compared by Newman–Keuls post hoc test. A simple linear regression analysis was used to assess functional dependence of Pb on PM_{10}, considering Pb as dependent variable and PM_{10} as independent variable. Stepwise multiple regression analysis was used to assess significant predictors of Pb from independent PM_{10} and dummy variables (locations and areas). The accepted level of significance was $P<0.05$. GraphPad Prism (version 5) was used for the analysis.

Results and discussion

Inhalable particulate levels in air

The concentrations (in micrograms per cubic metre) of inhalable particulates, $<PM_{10}$ and Pb found in different areas of Lucknow during 2002, 2003 and 2004 are summarized in Table 1 and shown graphically in Fig. 1. Among the residential areas, the concentrations of PM_{10} varied from 144 to 305 (avg., 196.5±20.87), 221–366 (avg., 266.8±19.10) and 141–242 (avg., 166.3±10.20) during 2002, 2003 and 2004, respectively. PM_{10} exceeded the standard by a factor of 2, 2.7 and 1.7 during 2002, 2003 and 2004, respectively. Among commercial areas, the concentrations of PM_{10} varied between 221 and 305 (avg., 258.2±13.22), 245–366 (avg., 321.7±18.5) and 178–242 (avg., 211.2±11.4) during 2002, 2003 and 2004, respectively. The concentration of $>PM_{10}$ exceeded the standard by a factor of 2.4, 3.2 and 2.1 during 2002, 2003 and 2004, respectively. Among industrial areas, the concentrations of PM_{10} varied from 203 to 207 (avg., 211.0 ±2.0), 211–252 (avg., 231.5±20.5) and 172–225 (avg., 218.5 ±26.5) during 2002, 2003 and 2004, respectively. It exceeded the standard by a factor of 1.4, 1.5 and 1.3 during 2002, 2003 and 2004, respectively.

All the observed values of PM_{10}, either for residential, commercial and industrial areas, were above their respective prescribed standard of the National Ambient Air Quality Standards (NAAQS) of 100 $\mu g/m^3$ for residential/commercial, rural and other areas and 150 $\mu g/m^3$ for industrial areas. However, PM_{10} was reduced significantly during the year 2004 because of the introduction of CNG buses for public transport replacing the diesel-operated tempos and three-wheeler vehicles from the trunk route. Cars with modern technology, improved quality of fuel, metalloid roads and other infrastructure reduce the generation of dust. The observed concentration of PM_{10} may be attributed to uncontrolled emission of auto exhausts, traffic obstruction and centralisation of offices and commercial places. There is no road in the city where vehicles can run smoothly with optimum speed range, i.e. 40–55 km/h either for engine/fuel efficiency (Onursal and Gautam 1997). Average speed is as low as 15–25 km/h which is the worst condition in terms of performance of engines and emission point of view. Major causes of air pollution are also the frequent digging of roads for gas pipelines, construction/repairing of roads, creation of traffic jams on both sides of railway crossings, poor condition of roads, operation of old vehicles, irregular parking of vehicles on the road, adulterated fuel, opening of shops at roadsides, road encroachment and congested, narrow lanes.

In the absence of zebra crossing, pedestrians are crossing the road anywhere/anytime, overruling the traffic lights and rules. Moreover, stray animals like dogs, horses, asses, pigs and cows roam around/on the roads and block the traffic flow. Sometimes, these creatures are also causes of accidents. Unplanned development of the city took place during the early phase of development. There are no planned roads. Most roads provide only two tracks without a divider (partition between to and fro movement of traffic). In reality, three to six rows of mixed vehicles comprising of bullock carts, bicycles, rickshaws, cars, maxi cabs, ambulance, fire-fighting bus, trucks, all kinds of vehicle attempt to move simultaneously, which creates barriers for each other. As a consequence, the driver has to blow the horn frequently to get road clearance in order to move ahead.

Lucknowites are commonly using the three-wheeler diesel-operated, fuel-inefficient Vikram Tempos/vehicle (10 ft L×4.5 ft W×6.5 ft H) with mean speed of 15–20 km/h. It is designed to accommodate six to eight persons

Table 1 Summary (mean±SE) of PM_{10} and Pb concentrations (in micrograms per cubic metre) in residential (n=4), commercial (n=6) and industrial (n=2) areas of Lucknow during 2002–2004

Pollutants	Area	2002	2003	2004
PM_{10}	Residential	196.50±20.87	266.75±19.10	166.25±10.18
	Commercial	258.17±12.06R	321.67±16.90R	211.17±10.38
	Industrial	205.00±2.00	231.50±20.50**C**	198.50±26.50
Pb	Residential	0.09±0.00	0.07±0.00	0.13±0.03
	Commercial	0.06±0.01	0.61±0.09**R**	0.32±0.07
	Industrial	0.89±0.04**RC**	0.63±0.16**R**	0.63±0.09**RC**

The letters show comparison of concentrations between areas and are significantly different either at $P<0.05$ (light) or $P<0.01$ (bold) from the respective area

R residential, *C* commercial

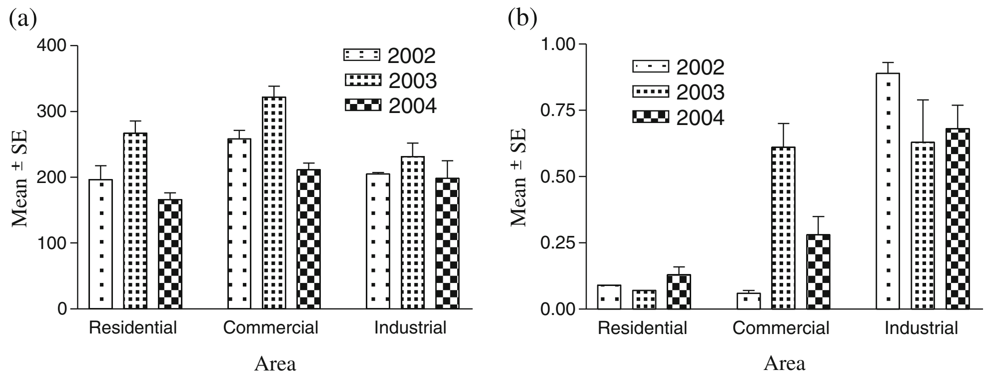

Fig. 1 Bar diagram showing average concentrations (μg m^{-3}) of PM_{10} (**a**) and Pb (**b**) in residential, commercial and industrial areas of Lucknow during 2002, 2003 and 2004

in the two opposite-facing rear seats and two to three persons in the front seat including the driver. Three doors and two windows are open, without any glass shield. It cannot protect the health of either the driver or the passengers. Passengers and drivers are directly exposed to auto exhaust fumes, road dust and other pollutants. These tempos are the major contributors of vehicular pollution in Lucknow. High-speed driving of these vehicles and maxi cabs in a rush to pick up passengers in competitive way is causing additional problems. CNG buses, the public transport system, do not meet the demands of the population as well as the daily city visitors from rural areas and other cities. Besides these, micro-meteorology, topography, geographical position and dust storm from the Thar Desert, Rajasthan, during the summer season have much influence on the pollution load and dispersal of pollutants. These factors altogether compound pollution problems and facilitate the build-up of the aerosol nuisance in the lower atmosphere.

Recently, researchers' attention has been shifted from suspended particulate matters (<100 μm) to PM_{10} and $PM_{2.5}$, which traverse down to sensitive areas of the lungs and cause series of disorders. More than 100 polyaromatic hydrocarbons (PAHs) have been identified in airborne particulate matter, and many of them are found with greater frequency in the air of cities with high levels of atmospheric pollution (Gil et al. 2000). It is estimated that many of the toxic components present in respirable particles are emitted by diesel motors (Bunger et al. 1998; Fromme et al. 1998). The IARC classified diesel motor emissions as probably carcinogens to humans (Group 2A), whereas gasoline motor emissions have been classified as possibly carcinogenic to humans (Group 2B). PAHs are generated by the incomplete combustion of fuels such as petrol, diesel, oil, coal and biomass, and they are metabolized ultimately into carcinogens (Yadav et al. 2010).

Air pollution kills an estimated 2.7 million to 3.0 million people every year, about 6 % of all deaths annually (171,227,261). About nine deaths in every ten due to air pollution take place in the developing world, where about 80 % of all people live (http://info.k4health.org/pr/m15/m15print.shtml). The concentration of number of particles and their size are more important than the concentration of particulate matter by mass. The effect of irritant particles in the respiratory tract depends much on particle size, their solubility, their penetration, deposition and clearance mechanism in the human respiratory tract. The fine particles may cause bronchospasm, pulmonary oedema and allergic alveolitis. The retention and deposition of inhaled sensitizing substances may produce allergic reactions or other sensitive responses. The two main respiratory diseases related to chronic exposure to particles are asthma and allergic alveolitis (Abbey et al. 1995; Forsberg et al. 1997).

Paediatricians of Lucknow indicated the occurrence of progressively increasing incidence of asthma among susceptible children in the age group 2–15 years. Particles containing pollen grains, fungi, virus or bacterial present in ambient air may play a key role in transmission of infectious diseases. Increased particulate exposure increases the incidence of bronchitis in the exposed population. Bronchitis or pneumonia induced by air pollution in the presence of pre-existing heart problems might hasten congenital heart and cardiovascular morbidity and mortality (Mead and Brajer 2006).

Certain respirable particles can cause cancer of the lung, fibrotic changes in the lung or pulmonary oedema after inhalation of arsenic and its compound, chromates and certain nickel-bearing dusts. Asbestos fibres can cause bronchial cancer and mesothelioma. Airborne particles containing PAH may act on lung tissues and cause cancer. The particles, if soluble, may be transported from the lungs to other parts of the body and may pose a risk to both lungs and other organs (WHO 1984). Many organic air pollutants adsorbed onto respirable particulates are known or suspected to be mutagenic and or carcinogenic to humans (Adonis and Gil 1993; Smith and Harrison 1996).

Lead level in air

The concentrations (in micrograms per cubic metre) of Pb during 2002, 2003 and 2004 varied from 0.08 to 0.10 (avg., 0.09±0.05), 0.06–0.08 (avg., 0.07±0.05) and 0.08–0.21 (avg., 0.13±.03) in residential areas; 0.02–0.09 (avg., 0.06 ±0.01), 0.29–0.90 (avg., 0.61±0.10) and 0.07–0.49 (avg., 0.28±0.07) in commercial areas, 0.84–0.93 (avg., 0.89± 0.04), 0.47–0.79 (avg., 0.63±0.16) and 0.58–0.77 (avg., 0.68±0.09) in industrial areas.

Measured Pb levels were well below the prescribed standards 1 and 1.5 μg/m^3 of NAAQS for residential, rural and other areas and industrial areas, respectively. Pb levels were significantly decreased in the ambient air because unleaded petrol has replaced leaded petrol in India since 1998. In the absence of leaded petrol, the observed lead concentration probably originated from acid batteries, vehicle workshops, paints and dyes, lead-bearing metal parts of automobiles and re-suspension of soil dust.

The fine particles may affect the skin on settling, but there are certain groups of particles which do not cause direct effects at their site of deposition but can pass into the blood stream viz. Pb and its compounds adsorbed onto fine particles which act as systemic poison that may cause learning difficulties, affect the central nervous system and cause memory deficits in children. Lead, the cumulative poison, is especially harmful to the developing brain. Ninety percent of Pb is retained in the skeleton. The large affinity of Pb^{2+} for thiol and phosphate-containing ligands inhibits the biosynthesis of heame and thereby affects membrane permeability of kidney, liver and brain cells. This results in either reduced functioning or complete breakdown of these tissues (Forstner and Wittmann 1983). Pb encephalopathy, a degenerative disease of the brain, may occur in adults with blood Pb level <120 μg/100 dL and 100 μg/100 dL for children (Harrison and Laxen 1981).

Statistical analysis

ANOVA revealed that the concentrations of both PM_{10} and Pb are significantly different between years and areas. On comparison, the average concentrations of PM_{10} in commercial areas during 2002 and 2003 are found to be significantly ($P<0.05$) higher than the respective residential areas, and in 2003, it is also highly significant ($P<0.01$) than the industrial area (Table 1). The average concentrations of it in industrial areas during all study periods (2002–2004) are found to be similar ($P>0.05$) while they differed significantly (either at $P<0.05$ or $P<0.01$) in residential and commercial areas, i.e. in both the areas, the concentrations increased significantly ($P<0.01$) during 2003 as compared to 2002 and decreased significantly ($P<0.01$) in 2004 from 2002 to 2003 (Fig. 1a). Similarly, during all study periods, the average concentrations of Pb in the industrial areas are significantly ($P<0.01$) higher than the respective residential (2002–2004) and commercial (2002 and 2004) areas and also highly significant ($P<0.01$) in the commercial areas than residential areas during 2003 (Fig. 1b). An estimation of Pb from PM_{10} was investigated by regression analysis and summarized graphically in Fig. 2a and b.

Health implication on the exposed population

A total of 660 drivers, 190 vendors and 162 traffic policemen were selected to record various symptoms related with the eyes. Drivers, 62.4 % (n=412); vendors, 56.84 % (n=108) and traffic policemen 68.5 % (n=111) expressed complaints related to eyes (Table 2).

Majority of the exposed were suffering from burning of eyes. Categorywise, 93.20 % of drivers, 74.07 % of vendors and 77.47 % of traffic policemen had complaints of burning of eyes. Drivers—51.45 %, vendors—44.44 % and traffic policemen—72.77 % also had eye watering problems. Constant irritation and redness in eyes occurred in 33.49 % of drivers, 21.29 % of vendors and 26.12 % of traffic policemen. Impaired eye vision was one of the major problems in the exposed subjects, and thus, drivers (25.01 %), vendors (20.37 %) and traffic policemen (13.5 %) complained of poor vision and needed eye corrections.

This study found higher prevalence of irritation symptoms among the drivers, vendors and traffic policemen. Symptoms of burning, 81.67 %; watering, 56.89 %; redness, 26.96 % and poor impaired vision, 19.63 %, were much more significant among these occupants (Table 3). These

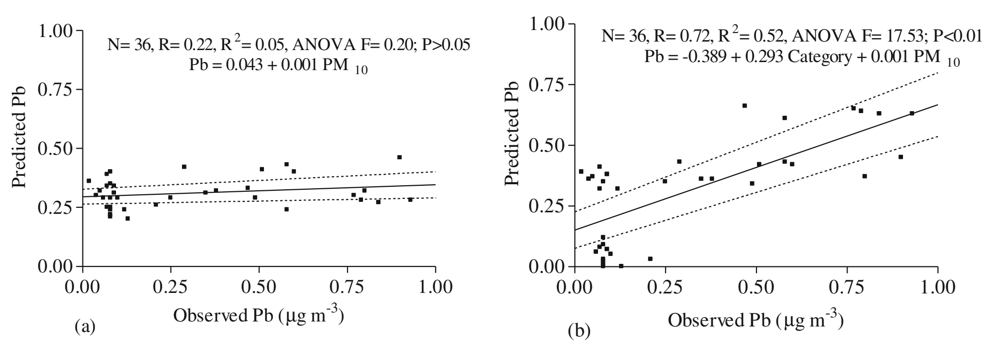

Fig. 2 Best fit regression equation for Pb from PM_{10} (**a**) and from PM_{10} and area (**b**) with lower and upper 95 % confidence limits for β (*slope*)

Table 2 Distributions of subjects surveyed for various symptoms related to the eyes

Subjects	No. of examined	No. with symptoms	Percentage occurred
Drivers	660	412	62.42
Vendors	190	108	56.84
Traffic policemen	162	111	68.51
Total	1,012	631	62.35

symptoms provide significant correlations between auto exhaust headache, burning, watering and redness of eyes. Earlier, Lercher et al. (1995) had reported an association between air pollution and (a) reduced visibility, fatigue, exhaustion, low mood and nervousness and eye irritation, and (b) decreased pulmonary function and respiratory illness (Krazyzanowski et al. 1992; Kan et al. 2009).

Automobile exhaust discharges several pollutants in the environment, e.g. NO_x and SO_2, particulate matter, PAHs, unburnt hydrocarbon, HCHO, which can also induce similar symptoms (McCare et al. 1994; Myran and Hedalen 1994; Yang et al. 1997). Vehicular traffic discharges air pollution at the breathing zone. This will ultimately lead to serious health hazards for occupationally exposed people and the population living in or around the corners of high traffic density (McCare et al. 1994; Williams and McCrae 1995). Moreover, the children, pedestrians, cyclists and people belonging to economically poor classes are under the threat of high risk of health problems (Wjst et al. 1993; Bates 1995).

Increased concentrations of vehicle exhaust carcinogens that have been associated with cancer risk like PAHs and volatile organic carbons, e.g. benzene and 1, 3-butadiene, have been reported in street vendors (Ruchirawat et al. 2005). There is substantial evidence that supports an association between vehicle emissions and cardiovascular disease, particularly mortality from cardiovascular causes (Pope et al. 2004a; Gehring et al. 2006; Miller et al. 2007).

Table 3 Ocular symptoms in drivers, vendors and traffic policemen

Total subjects	Ocular symptoms	Symptoms occurred	Percentage (%)
Drivers (n=412)	Watering	212	51.45
	Redness	138	33.49
	Burning of eyes	384	93.20
	Vision	103	25.20
Vendors (n=108)	Watering	48	44.44
	Redness	23	21.29
	Burning of eyes	30	74.07
	Vision	22	20.37
Traffic policemen (n=111)	Watering	83	74.77
	Redness	29	26.12
	Burning of eyes	86	77.47
	Vision	15	13.51

Statistical analysis

A total of 631 men (62.4 %) were found infected. The infection among traffic police (n=111; 68.5 %) was the maximum followed by drivers (n=412; 62.4 %) and vendors (n=108; 56.8 %) (Table 2). ANOVA revealed that symptoms between groups (exposed persons) did not differ significantly while differing significantly within groups. On comparing symptoms (Table 3), the burning in drivers was significantly higher ($P<0.05$) than the watering, redness and poor vision. Similarly, the burning in vendors and traffic policemen was significantly ($P<0.05$) higher than the redness and poor vision. In traffic policemen, watering was also found significantly ($P<0.05$) higher than the redness and poor vision.

Conclusion

The concentrations of PM_{10} found in the air of commercial areas were relatively high as compared to residential and industrial areas. Though the concentration of PM_{10} was reduced a little bit with the introduction of CNG buses as public transport, it was still found alarmingly high in all areas other than the NAAQS. The exposed drivers, vendors and traffic policemen are at high risk of eye-related problems due to discharge of auto fumes and polluted air at the breathing zone. Among the exposed group of people, vendors were most sensitive. The eye watering and especially eye burning were the most and significant common cause among all of the exposed population. A higher prevalence was observed among drivers, vendors and traffic policemen. Symptoms of burning (81.67 %), watering (56.89 %), redness of the eyes (26.96 %) and poor vision (19.63 %) indicated the presence of strong association between auto exhaust exposure and the headache, burning, watering and redness of eyes among the surveyed groups. Though this was a preliminary study consisting of random sampling of pollutants and ocular symptoms present in the exposed groups of the population, a detailed study is required on acute or chronic effects on humans.

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