Abstract

The current research work is an effort to cover different aspects of urban and transport related air pollution. Urban air quality monitoring and vehicular exhaust emissions monitoring are relatively new topics for a developing country like Pakistan. Euro II emission standards for vehicular exhaust emissions have been opted as Pak II in the country, since 2009. The fuel quality is substandard than Euro II standards. Emission factors or any local urban driving cycle for different classes of vehicles has not yet been established by any of the Provincial or Federal EPA. The transport system and the land use developments have very low transport sustainability. Public transport infrastructure is of conventional quality, forcing people to use their own transportation for their trips. The air quality monitoring through sophisticated instruments at different sites like, hotspots, roads, industrial area and rural areas, is a very expensive task for a developing country like Pakistan. Therefore, modeling is a useful technique to assess air pollutants level at different spots, especially road sides and in big cities like Lahore, Pakistan.

An attempt has been made to find out diurnal & monthly mean pattern of air pollutants, their interrelationship and their dominant sources through hourly and monthly data analysis. Horiba air quality monitoring instruments have been used to monitor hourly, monthly, seasonal air quality and meteorological data of Lahore. Lahore is a semi-arid region with low rain-fall, hot & humid summers and cold dry winters. Annually, highest Air Quality Index (AQI) (132 to 185) has been observed from November to February due to inversion at low wind speed (< 1.5 m/s monthly average), low temperature (15°C to 21°C monthly average) and low solar radiations (104 to 140 W m^{-2} monthly averages). AQI remained low (74 to 85) from June to August due to relatively heavy rain, relatively high wind speed (1.59 to 1.85 monthly averages), dispersion as a result of high temperature (30°C to 32°C monthly average), high solar radiations (211 to 236 W m^{-2} monthly averages) and summer vacations to schools. With an analogous diurnal trend, the AQI remains low at day-time. High ratio of CO/NOx indicates that mobile sources are dominant contributor to CO; and low ratio of SO_2/NOx indicates that point sources are dominant contributor to SO_2. CO has a significant positive correlation with NO, NO_2, NOx, CH_4, SO_2 and RH. While CO has negative correlation with O_3 and temperature. The positive correlation of CO with NO, NO_2, NOx, CH_4 and SO_2 explains 4-stroke petrol engines as a common source for these pollutants. $PM_{2.5}$ has a significant positive correlation with

SO_2; which explains diesel engines as a common source for $PM_{2.5}$ and SO_2. O_3 has a significant negative correlation with NO, NO_2, NOx, CH_4, CO and relative humidity. While a significant positive correlation has been observed among O_3, temperature and solar radiations.

Transport sustainability is a novel topic for public and policy makers in the country. Many efforts have been performed by the provincial Government to control traffic congestions through introduction of overhead bridges, under passes and u-turn bridges in the city. A ring road has also been introduced to link different parts of the city. A 27 Km long metro bus has been introduced on Ferozepur road and 31 Km long metro orange line train project is under construction. CNG buses have been promoted in the city. But most of the the land use development policies do not take transport sustainability into account. This research is intended to find out sustainable transport indicators and transport sustainability index for the five roads of Lahore, Pakistan. The main indicators of transport sustainability are taken as shifting of modes from private to public vehicles, land use planning and sustainable operations. In a way thirty-five transport sustainability indicators have been selected. The opinion of stake holders has been taken by a questionnaire by randomly interviewing around four hundred citizens. The social survey pointed out that distance from bus stop, time taken and length of journey ($\geq$ 4 out of 5 grades) are important factors in preventing people from using public transport. Time, convenience, safety, reliability, relaxation and health ($\geq$ 4 out of 5 grades) remained important factors in the choice of public transport. Cheaper fares, availability of school/work bus, more reliable service, more bus routes and extended bus service ($\geq$ 4 out of 5 grades) were considered as important factors to promote public transport. None of the advertisement technique was ranked above 4 to promote public transport during the survey. Transport sustainability index of Ferozepur road, Gulberg main boulevard road, Jail road, Mall road and Multan road were 47.14, 38.57, 40, 34.29 and 34.29 respectively.

Another main task of the research is to find out emission factor of different classes of vehicles to model the certain air pollutants level in five different main streets. Motorcycles constitute more than 50 % of the vehicular traffic on most of the roads. The percentage of cars varies from 26% at Multan road to 37% at Jail road. The background urban emissions data has been monitored through air quality monitoring station installed at Town Hall building at Mall road. The air pollutants level has been modeled with the help of Operational Street Pollution Model (OSPM). The data of

street configuration, background urban air pollution, meteorological conditions, diurnal traffic count and emission factor of vehicles has been monitored to model the pollutants level at different streets. A significant correlation (r-value > 0.5) has been observed between modeled and observed results for all the streets for NOx, SO_2 and CO levels, except for NOx level at Gulberg (r-value= 0.42). The better modeling results have been observed for those streets which are in relatively polluted spots and are close to the background urban air quality monitoring station.

Overall the air quality index of the Lahore city remains high in winter season due to meteorological conditions. The $PM_{2.5}$ level remains much higher than NEQS throughout the year especially in winter season. Petrol engines are the main source of CO and diesel engines are the main source of SO_2 emissions in the city. O_3 levels remained high in summer season during a calendar year and at day time during a day. The transport sustainability index is very low (< 50) for all five selected roads. People were found reluctant to use public transport due to factors like much time consumption, inconvenience and distance from bus stop. There is need to introduce many innovations in land-use development and public life style to promote transport sustainability in the city. The signal free tracks have improved the speed of vehicles at many roads in the city. It has been calculated that with 10% decrease of cars and 10 Km/hr gain in speed (from 40 to 50 Km/hr) can reduce the CO and benzene emission factor of cars by 33.2% and 25.7% respectively. Each vehicle in the city has much high emission factor as compared to modern vehicles, due to substandard fuel quality and relatively old engine types in the city. A significant correlation has been found among observed and modeled results on five selected roads of Lahore. And modeling technique has been found to show significantly acceptable results of street air quality modeling, on different roads of Lahore.