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GIS Based Monitoring and Assessment of Vehicular Pollution

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***Abstract*- The rapid urbanization in our societies shows a tremendous increase in the number of motor vehicles. The vehicular traffic is now recognized as one of the main sources of air pollution in urban cities that is the region now a days ambient air quality drastically change. The revolution in the automobile industry and liberalized economy has led to tremendous increase in the vehicle ownership levels. The urban population growth, economic development, energy consumption, growing transportation demand and living standards are major sources of vehicular pollution. The ambient air pollutants concentration are exceed is as compare to NAAQS and WHO guidelines. In this paper is basically assessment of vehicular with help of mathematical calculation for the emission and concentration of various ambient air pollutants. Than it integrate existing emission calculation with GIS (Geographical information system) component. It also gives summary of basic road emission than concentration of the pollutants. The assessment is based on the GIS technology. The integrated emission evaluation system offers entirely new ways of using the emission model and gives additional visualization and analysis possibilities.**

Keywords: Exposure, GIS, Mapping, Megacities, Pollutants, Vehicular emission

I. INTRODUCTION

India is fast growing among the developing countries and the rapid urbanization and industrialization have resulted in the tremendous rise in population of Delhi, the capital city of India and its surrounding areas, which has further led to increase in energy consumption and remarkable increase in vehicle fleet which has raised serious environmental concerns in the region, transport, and housing which contributed to an increase in air pollution ([1]; [2]; [3]; [4]; [5]; [6]). The National Capital Territory of Delhi (NCT) covers an area of approximately 1500 km^2 including parts of the neighboring states of Haryana, Uttar Pradesh, and Rajasthan. The region has grown rapidly over past 20 years. Delhi being the capital city is the center of socio-economic, cultural, political and major tourism activities of the country. The city also acts as a major center of trade and commerce and is the intersection point for five national highways and expressways, carrying large volumes of heterogeneous passenger and freight traffic. The national highways and other major road networks carry intra and inter-city traffic traversing to and from the different parts of the country. The transport system of Delhi consists of a well-developed road network, based on ring and radial pattern with large fleet of buses. The major share of travel needs of Delhi commuters is met by road based transport systems though metro has been inaugurated in the year 2002. There has been a major improvement in transport infrastructure in recent years in terms of flyovers, road widening, new roads development and introduction of metro rail corridors along major routes to accommodate increasing capacity of wide range of vehicles. Due to continuous increase in population and employment opportunities, the vehicular number is increasing exponentially with demand over decades leading to serious traffic problems of congestion, delays, safety, system management and above-all, air pollution.

The rapid urbanization in Delhi has resulted in a tremendous increase in the number of motor vehicles with the increase in population and urban mobilization. The vehicular traffic is now recognized as one of the main sources of air pollution in Delhi exhibitting noticeable impact on air quality [6]; [7]; [8]. The emission of criteria pollutants namely Carbon Monoxide (CO), Nitrogen Oxide (NOx) and Particulate Matter (PM) due to vehicles is estimated through the International Vehicle Emission (IVE) model, which includes the different driving modes of vehicles and meteorological parameters. The estimated emissions of Carbon Monoxide (CO), Nitrogen Oxides (NOx) and Particulate Matter (PM) sourced from different types of vehicles in the year 2008–09 are found to be 509, 194 and 15 tons/day respectively. The diurnal variation of emissions of air pollutants shows two peaks, which are fortunately matching with the morning and evening office hours. The emissions of CO and NOx due to personal cars (PCs) are found to be about 34% and 50% respectively, and the emission of CO due to 2W (2-Wheelers) is about 61%. Similarly, the Heavy Commercial Vehicles (HCVs) are contributing PM about 92%. Vehicular emission load reported by the Delhi Pollution Control Committee (DPCC), Govt. of NCT of Delhi is as under On-road transport sector is one of the prominent sources of emission. In recent decades, number of vehicles plying on Indian roads has grown rapidly due to fast economic development as well as urbanization. However, the economic boom was accompanied by an overall decline in air quality ([11]; [12]).

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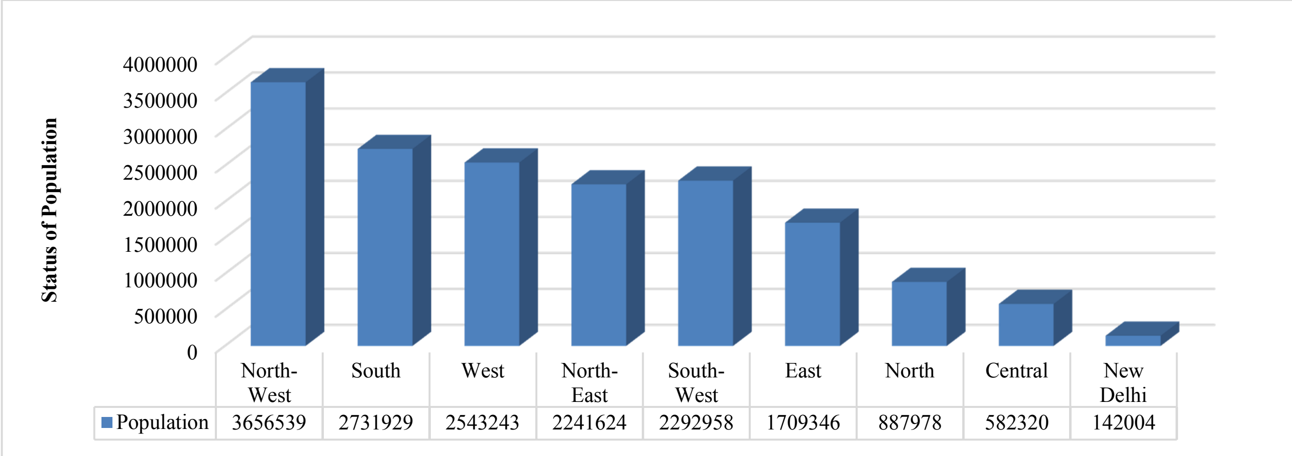
Figure 1:Population Density per square kilometer (District Delhi)



Source:[36]

India is a developing country and vehicle emission controls are implemented after 2000 in different stages all over the country. In last two decade, the vehicle numbers have increased by more than five folds (i.e., 21 million in 1991 to 114 million in 2009) ([13]). With rising transport demand, India became 7th largest vehicle producing country in the world ([14]). Around 80% of passenger and 60% of freight movement depend on road transport ([15]). It has been reported that steep rise in vehicle number and poor emission control practices results in serious air pollution problem ([16]). On-road vehicles were believed to be the single largest source of major atmospheric pollutants till 1998 (e.g., [17]; [18]) and continued to remain a large source especially in developing country. Emission of airborne pollutants from transport sector accounts for more than 50% of gross emission in urban as well as semi-urban areas (e.g., [19]; [20]; [21]; [22]; [23]; [24]). Thus, an exact estimation of emission from on-road vehicle is crucial to understand the air quality in Indian Territory.

Figure 1 above shows the population density of the various districts of Delhi. The graphs arranged in decreasing order such that the highest value of population shows as: northwest>South>West>North East>South West> East>North>Central>New Delhi. The minimum population shows in New Delhi and maximum in North West Delhi.

The status of the registered has increased from 31.64 Lakh in 1999 2000, while it touched 74.53 lakh in 2011-12.

II. EFFECTS ON HUMAN HEALTH

Traffic-related atmospheric pollutants including ultrafine particles (UFP, <100 nm in diameter), black carbon (BC), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs), are believed to adversely impact the health of populations living and working near roadways. Proximity to major roadways and exposure to traffic related atmospheric pollutants may be associated with a number of respiratory and cardiovascular issues including asthma, reduced lung function, adverse birth outcomes, cardiac effects, respiratory symptoms, premature mortality, and lung cancer ([25]). Most recently, diesel exhaust was officially classified as carcinogenic by the International Agency for Research on Cancer (IARC) of the World Health Organization ([26]). Reference [27] found that children who lived within 500 m of a freeway had substantial deficits in lung function, when compared to children who lived 1500 m or more from a freeway. A cohort study in Toronto, Canada suggested that traffic proximity (residence within 50 m of a major road or 100 m of a highway) may be associated with an increase in circulatory mortality of over 40% [28]. In Canada approximately 4 million and 10 million people live within 100 m and 250 m of a major road, respectively, based on 2006 Census data [29].

Reference [30] also reported neighborhoods with heavy truck traffic within 200 meters of their home had increased risk of asthma hospitalization the hospital admission for asthma amongst children ages 0-14, and residential proximity to roads with heavy traffic. Reference [31] found the approximately 10-20% increase in the risk of premature birth and low birth weight for infants born to woman living near high traffic area.

Fig 2: graph shows the maximum death in Delhi due to respiratory diseases in years 2011, 2010, 2012, 2013 respectively. The minimum death shown in 2009 while year 2013 shows decrease in the death of human population as compared to the last three years.

Delhi is the national capital of India with its population,according to estimated figures from Census of India, in 2013 as17.1 million and 17.8 million in 2014. Delhi shows the huge growth in its population every year which is estimated to cross approximately 20 million in 2020.

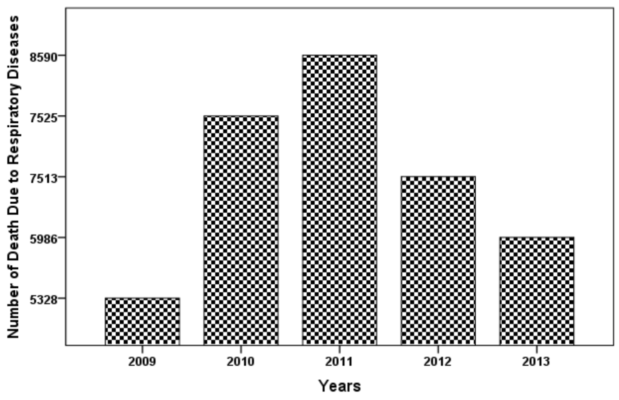


Figure 2: Death due to Respiratory Disease in Delhi

III. METHODOLOGY

Emission from the transport sector depends mainly on type of transport and fuel used. Major constribution of atmohpheric pollutants sources from transport sector. The emission load from transport is calculated using the following equation ([32]; [33]; [7]; [8]).

$$Ei = \sum (Vehl \times Dl) \times EFl \qquad (1)$$

Where,

E_i= Total Emission of compound

Vehl = Number of Vehicle per type

D_l= Distance traveled in a year per different vehicle type

EF_l, *km* = Emission of compound, vehicle type per driven kilometer

The population of 2-Wheelers on road in 2009 was found to a huge magnitude of 67.9 million comprising of 2 strokes scooter and 4 stroke motorcycle contributing to nearly 52% and 48% to the total 2W category respectively. Age-wise look in to this category shows that the 10 year old vehicle number is quite large followed by that of 5 year old vehicles. The 2nd most dominant category on Indian roads are those of cars and jeeps which are used as personal and multi utility passenger vehicles such as taxi, etc.

The Microsoft Excel tool has been used for calculating emissions from transport sector using Eq. (1).

The secondary data for traffic volume has been sourced from the CRRI Report. National vehicle emission control standards along with deteriorated vehicles are two important aspects that affect emission factor. The emission estimates vary considerably over the past 20 years in India. On-road vehicle emission depends on various factors like vehicle emission control technology, vehicle type, age of vehicle and Vehicle Kilometer Traveled (VKT). So, to establish a refined emission from transport sector, a technology based dynamic vehicular emission factors are applied on vehicle types and their corresponding VKT. A bottom-up approach is adopted to calculate the emission of different pollutants at grid level as well as district level using technological vehicle classification, corresponding dynamic emission factor and annual VKT.

Vehicle population data for various vehicle types has been obtained from [34] and [13]. Six vehicle categories have been considered in the present study which include two-wheelers (2W), three wheelers (or auto-rickshaws - 3W), passenger cars (PCs), Buses, Light commercial vehicles (LCV) and Heavy commercial Vehicles (HCV). Annual average vehicle kilometer travelled is estimated as 10,000 for passenger cars; 36,000 for taxis and auto-rickshaws; 50,000 for buses and 30,000 for HCV and LCV (Guttikunda and Calori, 2013) and 27,000 for 2-wheelers (2W) (Sahu et al. 2011). Buses and 3Ws have been assumed to use only compressed natural gas (CNG) as fuel. On the basis of engine type, 2W vehicles have been classified as 2-Stroke (2S) and 4-Stroke (4S) with use of gasoline (or petrol) as fuel. Amongst the total 2W numbers, 72% are motorbikes, and rest 28% are scooters. Since 4S-2W emits less pollution load in comparison to 2S-2W, thus a ratio of 72:28 has been considered for 4S-2W and 2S-2W [35]. The age-wise distribution of vehicular population of Delhi has been taken from [35]. The numbers of vehicles monitored on different types of roads in the year 2008–2009 has been used from [36]. According to the Integrated Mobility Plan for Gurgaon-Manesar Urban Complex, on an average about 0.3 million vehicles are entering and exiting Gurgaon, including NH-8 expressway each day. The maximum number of vehicles entering/exiting Gurgaon are through NH-8 (from Delhi side), followed by Mehrauli-Gurgaon road and NH-8 from Rewari side. About 0.5 million vehicles commute between Delhi and Noida and vice-versa, on daily basis. In addition, major congestion points in Noida were also identified which included Agarsen Marg, Kalindi Kunj, Filmcity to Mahamaya Flyover [37]. Also, traffic characteristics at various locations in NCR have been taken from CES primary survey [39]. Thus, nearly 2.2 million vehicles from all surrounding areas of Delhi contribute to the total vehicular population [24].

A. Emission Estimation

All emissions were estimated on the basis of activity data at district level as well as grid level. The district level emission from transport sector were estimated based on technology specific vehicular EFs for India ([9] ARAI;[38]; [35]). The technology based age specific vehicle categories are calculated for each district using multiyear registered database and corresponding dynamic emission factor were applied to the vehicle number along with VKT to obtain the total emission from a district. The detailed formulation is discussed elsewhere and used by us [24] and also included by [10]. The total emission is estimated using Eq. (1). EFs are derived using information of existing vehicular technology based on emission norms implemented time to time. These are then applied to the vehicle numbers and VKT.

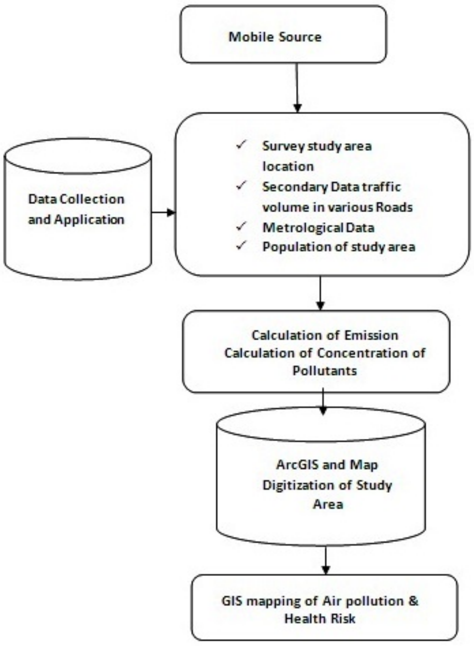


Figure 3. Vehicular pollution mapping with integration of GIS

The Gaussian solution for linear sources which is based on the principle of overlaying various component, which further assumes the concentrations of emitted substances at the receiving equal to the sum of dispersions of all infinite points sources which are together in line source. The model formulation for finite and infinite line sources is developed from Gaussian – plume equation, which is given below.

$$(x, y, z) = \frac{Q}{\pi u \sigma_y \sigma_z} exp \left[\left(-\frac{(z+H)^2}{2\sigma^2 z} \right) exp \left(-\frac{(z-H)^2}{2\sigma^2 z} \right) \right] \quad \text{Eq(2)}$$

Where

C(x,y,z) is the concentration unit (gram/meter3) at some point in space with coordinates x,y,z

Q = the emission rate of the pollution source (in gram/second)

u = the average wind speed in (meter/second)

y = cross wind distance

z = vertical distance

σy =the standard deviation of the plume in the y direction (meter)

σz=the standard deviation of the plume in the z direction (meter)

The Line source is assumed as a line of infinitesimal point source The ground level concentration of gaseous pollutants can be obtained by integrating Eq(2) along the leangth of the line source.

Source of emission at ground level,y=0,z=0

So Concentration is $c(x, 0,0) = \frac{Q}{\pi u \sigma_y \sigma_z}$ Eq (3)

IV. RESULT AND DISCUSION

This paper helps to examine the assessment of vehicular emissions with the help of advanced modern technology based study like GIS. Spatial distribution of urban air pollution concentration is very useful from a technology based assessment. The spatial patterns of pollution resulting from policy or other interventions and provide improved estimates of exposure for epidemicological studies. Delhi has recorded the highest increase per capita road length decrease and more importantly the number of vehicles per km of road has tremendously increased. This indicates the number of vehicles registering has increased fivefold in Delhi. The rapid growth of personalized transport in Indian cities gives rise to serious issue due to increment of air pollutant problems.
In the current scenario, Delhi is facing the highest vehicular emission load. In recent times, Delhi NCR is rapidly modernizing and commercializing. The considerable magnitude of air pollution increases the number of people suffering from respiratory and cardiovascular diseases. That is the major issue which results in premature deaths in India. There is a need to control population growth and vehicular air pollution in the megacities. Special efforts should be made for educating the general mass and local leaders about the adverse effects of a large population and vehicular pollution through specially designed information, education and communication activities. Upgrading the quality of Indian fuel, enforcing higher emission standards and regulating traffic can reduce the pollution caused by the explosion in the number of automobiles in megacities. Those who use personal vehicles should be encouraged to use the public transport system. State transport service should set up better vehicular standards, and more research and development should be encouraged in vehicle technology. Air pollution should not be a responsibility of government alone but mass and local leaders should be encouraged to make dedicated efforts to eradicate the air pollution problems. The policy aimed at overall development should certainly include efforts to control population, private vehicles, and air pollution for better health of the present and future generations.

V. CONCLUSION

The emissions can be estimated on the basis of activity data.In last two decade, the vehicle numbers have increased by more than five folds (i.e., 21 million in 1991 to 114 million in 2009.The observation reveals that vehicular air pollution is a major source of air pollution causing deterioration of air quality. The present method provides a decent way to estimate the air pollution with the use of available techonology. This estimation can be very helpful in determining the necessary measures that needs to be taken to improve environmental conditions.

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