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A Review on Impacts of Road Activities and Vehicular Emissions on Native Ecosystems in Mountainous Region

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Abstract

India's transport network is one of the most extensive in the world. Road network is vital for sustained and inclusive growth of the economy and consolidation of social diversification of the nation. When compared to other transport means, the road transport is considered to be more flexible and consumer friendly as it provides door-to-door service to the people even in the remotest parts of the country. With increasing population, there is immense load on natural as well as man-made resources. With growing development, people are more and more dependent on transport system for fulfilling their needs and expansions. Thus, these road activities greatly affect the environment qualities. Present review discusses the impacts of road activities on soil, water, and air quality and noise nuisance.

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Introduction

Road projects are meant to enhance the economic and societal well being of people. Better conditions of roads can minimize travel time and lower the costs of transport and improve earning and ultimately the living standard. This two-way interaction gives benefits to consumer and also such accessibility creates more and more demand for further development. Transportation has become crucial in development and economy of the country and is an important part of our daily lives.[1] Transport leads to growth by providing trade both at national and international levels and by increasing access to basic requirement of living i.e. health and education facilities. Positive side of transport is undeniable. However, despite the wide range of benefits, transport activities bring variety of adverse impacts to the degradation on environment qualities and human health. The expansion of roads has affected the air, water, soil and biodiversity.[2]

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Road activities create damage to sensitive ecosystems,[3,4] soil degradation, changes in drainage system and thus, contaminate ground water. Contamination of vegetation by airborne trace metals is remarkably more in urban areas, especially along highways.[5,6] Traffic emits pollutants and disperses dust, which get settled on surface of leaves and may block stomatal opening and prevent water and gas exchange with the atmosphere. The dust layer also decreases amount of sunlight reaching the leaf surface, which may interfere with the normal plant processes like photosynthesis, transpiration and respiration and can cause physical damage to plants.[7] Road activities include various processes like designing and management of roads, parking facilities, designing of vehicles etc. Such changes increase detrimental impacts up to varying degrees. Though, such activities are detrimental for environment but still contaminated soils, water, plants and air reduces proportionally as go off the road.[3,8]

Trees on roadsides face stressful growing environment, such as air pollution. Heavy traffic suppresses plant's performance and shortens life span. The pollutants released from vehicular exhaust emission bring changes in growth of the plant species growing close to the roads and could involve in the extinction of some important species9. The national highways network of India is a network of highways spreads throughout the country connecting major cities, ports, state capitals, big industrial and tourist centers, etc. and managed and maintained by agencies of the Government of India. The state highways provide connectivity with the NH, district headquarters, tourist centers etc. These are managed by the governments of those states through which, they pass. Village roads or link roads are not more than 2-3 meter in width, which are generally in poor condition. The aim of this review is to study the effects of road activities on native ecosystem (air, water, soil and noise). Roads taken under present study are national highways, state highways and link roads.

Effect on Air Quality

Air pollution is the contamination of air, which deteriorates the health of living beings. Effects of air pollution include damage to non-living things like historical monuments, statues, heritage buildings; agricultural damages like low crop yield, poor growth; and ultimately climate change (gases released from vehicular emission absorb energy emitted by the earth, which leads to global warming).[10] Fossil fuel burning by combustion engine comes up with greenhouse gas accumulation in the atmosphere. Carbon dioxide is the main gas responsible for global warming and concentration of this gas is rising exponentially. The road traffic exhaust emissions have been the cause of great concern about tropospheric ozone production.[11,12]

With the increasing amount of vehicle usage, less public transport and more personal vehicles; there is huge load on fuel consumption, which affects our non-renewable natural resources stocks and such situation can create the fuel crisis in world.[13] Increase of vehicle fleets is the major triggers for the increase in air pollution levels and degrading air quality.[14] Important chemical pollutants emitted by vehicles are Carbon monoxide (CO), Sulphur Dioxide (SO_2), Nitrogen dioxide (NO_2) and total suspended particles.[15] The traffic situation in an area is also a source of heavy metal contents in the roadside dust and plant samples.[16] For determination of air pollution and it health risk due to traffic congestion, two models Emission and Dispersion modeling were mainly implemented.[17] The application of CALINE-4 model was studied for air quality management purpose along the road/highway corridor(s) in Delhi.[18]

Faiz[19] has reported that two stroke motorcycles were responsible for releasing huge amount of hydrocarbons and particulate matter. Ingle[20] reported that the shop-owners working at the highway roads sides are more prone to health issues caused by air pollutants due to highway traffic.

Seasons play vital role in the concentration of air pollutants. The concentration of CO_2 (370.92 ppm), SO_2 (0.40 ppm), NO_2 (0.40ppm) and HC (0.30 ppm) exceeded the permissible limit for a one-hour averaging time during dry season, whereas, concentration of all pollutants was within limit during wet season.[21]

Shi[22] studied and found the presence of ultra-fine particles at roadside and with increasing distance particle number concentrations decreased

approximately 5 times within 30 m of major roadway (>30,000 vehicle/day). Study was conducted by Janssen[23] to determine the air pollutants like benzene, PM (2.5 and 10) and black smoke in and around 24 schools in Netherlands and found that $PM^{2.5}$ and black smoke increased with increase in truck traffic and decreased as go away from highways (40,000-170,000 vehicles/day).

Zhu[24] observed the wind speed and direction, traffic volume, ultra-fine particle concentration, Black Carbon and Carbon monoxide in Los Angeles and found that the concentration of particles decreased exponentially as goes from 17 and 150 m downwind from the highways. Zhang[25] studied that particle size grew bigger than 0.01 um because of condensation at area in between range of 30-90 m downwind of highways and beyond 90 m, there was particle growth (>0.1 um) and shrinkage (<0.01 um) due to evaporation. There was difference between chemical composition of ultra fine particle near highways than that has undergone atmospheric transformation during transport to downwind locations. Fisher[26] measured particulate matter (2.5 and 10), particle-bound PAH and VOC concentrations at outdoor and indoor on roadside houses with high and low traffic in city of Amsterdam. Particle-bound PAH and VOC in indoor and outdoor of heavy traffic areas were 2 times higher than low traffic areas. Roorda-Knape[27] studied PM (2.5 and 10), Black Smoke, NO_2 and Benzene in residential area within distance 300 m of highways. It was observed that at outdoor, black smoke and NO_2 concentrations decreased while moving away from highways, whereas PM S(2.5 and 10) and benzene concentrations did not get affected with distance.

Wagh[28] evaluated the impact of air pollutants on the vegetation along the road in Jalgaon City, Maharashtra. The species along the roads were *Azadirachta indica, Ficus religiosa, Ficus benghalensis* and *Terminalia catapa*. Total chlorophyll content of trees at roadside with heavy traffic was highly affected. Reduced leaf area was observed. A study was conducted to observe the effect of urban air pollution on roadside tree species of *Pongamia pinnata* with special focus on epidermal characteristics and reported marked changes in epidermal traits with more number of stomata and epidermal cells/area in leaf samples from polluted sites than those from control site. The length and width of guard and epidermal cells reduced greatly in leaves of polluted sites as compared to control sites.[29]

A study of air pollution tolerance index (APTI) and anticipated performance index (API) was conducted alongside roads. Tree species selected were *Toona ciliata, Ficus palmata* and *Grewia optiva*. Results indicate that chlorophyll content (1.28-

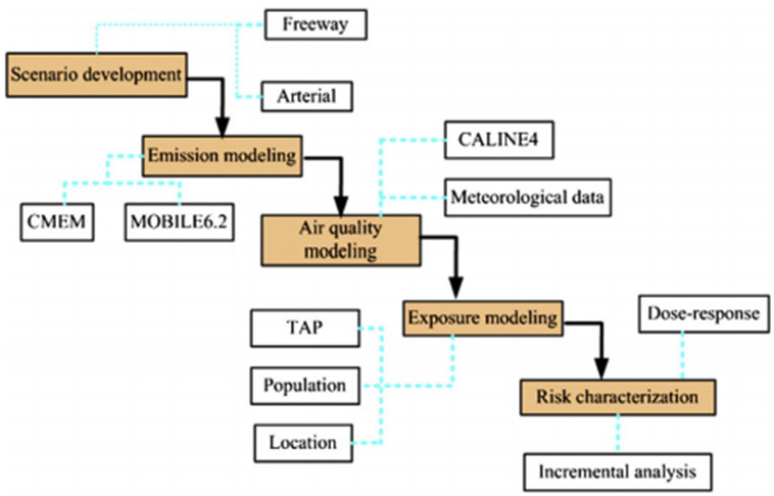

Fig. 1: Diagrammatic presentation for models for analyzing health risks due to traffic and congestion[18]

2.04 mg g^{-1}) and leaf abstract pH (5.69-6.38 mg g^{-1}) increased as go away from roadside. The relative water content (72.12-63.86%) and ascorbic acid (2.86-1.87 mg g^{-1}) decreases as distance from roadside increases. Value of APTI was maximum in *Toona ciliata* (9.98) followed by *Ficus palmata* (8.53) and *Grewia optiva* (6.93). *Toona ciliata* showed good results for APTI and API thus can be recommended for plantation along roadside.[30]

Atasoy[31] compiled and reviewed a comparative study to evaluate the impact on roadside vegetation of paved or unpaved roads. Both had different impacts on roadside vegetation in context to density of roads, biodiversity, level of deforestation etc. Biodiversity, which was already disturbed by human activities, may get worse with time. Woody plantation was more preferable on roadside than shrubs and grasses, as it provides more safety and aesthetic value.

As a mitigating strategy, a study was conducted to evaluate the effectiveness of sound wall and vegetation barrier for minimizing the air pollution emitted from traffic related air pollutants (ultra fine particle and $PM_{2.5}$). At wind speed of 1-2 m/s sound wall barrier was more effective for decreasing $PM_{2.5}$ (up to 53%) than ultra fine part (0.5%) and vegetation barrier also gives good result (up to 50%). Both barriers helped mitigating the air pollutants.[32]

Effect on Water Quality

Water is a required condition for public health and development and a fundamental human right[33] as per EPA guidelines, transportation affects water quality. Premises such as gas stations, service stations, maintenance shops etc. degrade water quality through spillage of oil, and dirt; mishandling during refilling of fuel etc. releases waste into nearby water bodies and contaminate it. Pollutants either get directly drain out into the natural water body, or are air-borne and then get settled down. Deicing is a noteworthy contributor to road runoff problems in hilly terrains. Rock salt (NaCl) is a common deicing agent, allows highway travel during snow conditions in hilly areas. Salt is cheap and effective but creates serious adverse impact on roadside vegetation, loss to soil health, drinking water and aquatic life. Due to presence of salt, capacity for ion exchange, permeability, aeration and increasing alkalinity of the soil decreases with increase concentration of ions.[34]

Research was conducted on three main highways of Tehran city and results showed that presence of heavy metals like zinc, copper, nickel, cadmium and lead in run off of the highways was mainly due to heavy and lengthy traffic.[35]

Study was conducted on six-rainfall road runoff from three different types of roads. Result concluded that concentration of COD, total N, total P and Pb go beyond the fifth standard of the Environmental Quality Standards for surface water.[36] Water quality of road run off was analyzed at 21 locations surrounding the Brisbane city (Australia). Samples from outlet points have showed higher concentration of acid-extractable copper and zinc, which was due to brake pad and tire depletion caused by moving traffic. There was notable amount of sediment present in road runoff, which gets settled in water within 24 hrs (laboratory conditions), indicated the presence of heavy metals.[37] With the downward flow of road run off discharge, concentrations of total hydrocarbons, aromatic hydrocarbons, and heavy metals were increased. At a specific site prominen PAHs found-phenanthrene, pyrene, and fluoranthene whereas, prominent metals detected were zinc, lead, cadmium and chromium.[38] Salt runoff spoils vegetation, which ultimately affects the seedlings, flowering and fruiting of sensitive plant species; foliar, shoot and root injury; and growth reductions.[34] Heavy metals, organic contaminants and microorganisms were reported as the prominent contaminants of serious concern in runoff.[39] A relationship was observed between storm events and increased incidence of gastrointestinal disease in the U.S., due to the transportation of human pathogens to drinking water supplies by storm flows.[40]

Heavily travelled highway in the city of Cincinnati was examined and results indicated that Zn, Cd and Cu were present in exceeded concentration than water quality discharge standards.[41] Concentration of contaminants like metals, anions and hydrocarbons, depends on characteristics of particular site such as traffic volume, zone of the road drained and dimensions of the stream. Such pollutants have detrimental effect on macroinvertebrate community.[42] Water moving on and alongside roadways may have high levels of various forms of dissolved nitrogen ion, and weathering process brings phosphorus ions when it reached surface waters.[43]

Effect on Soil Quality

Soil is an important part of the environment, and act as a primary medium on which various living and non-living components flourish. The most sudden effect of development of roads on soil is the degradation of the fertile soil.[44] Road activities destabilize the delicate stabilizing factors, like vegetation, slopes, micro flora and fauna. Contamination of soil may arise from heavy traffic activities on very heavy traffic roads. Metals such as Zn, Cr and Pb persist in the soil for very long time. Pollutants settled in roadside soil can effects the growth of vegetation and the life span of soil organisms thus, increasing the soil degradation. Such effects are usually occurring at confined level, affecting only a restricted band.[45]

Deicing salts, mainly sodium chloride, calcium chloride, potassium chloride, and magnesium chloride increase ions concentration in the soil, which ultimately alter pH and chemical composition of soil.[44,46,47,48,49,50]

The effect of automobile pollution on seedling growth on some roadside tree species (*Cassia surattensis, Lucaena leucocephala, Parkinsonia aculeata, Sesbania sesban*) were studied and it was reported that seeds of most of species from polluted zones showed notable reduction in germination as compared to control. It was reported that the biomass of *Alstonia scholaris, Pongamia pinnata, Cassia siamea* and *Peltophorum pterocarpum* regarding leaf dry weight was affected in polluted area of Karachi city than unpolluted areas.[51]

Abechi[52] investigated heavy metals in roadside soils. The soil samples were analyzed for the levels of Cu, Ni, Cd, Pb, Mn, Co and Fe. Results indicated the following trend of total metal content: Fe > Zn > Mn > Pb > Cd > Cu. Vehicular emissions were the main reason for metal pollution in the soil. The consequences of vehicular emission on concentration of heavy metals along selected roads of different traffic flow was studied and trend of concentrations of metals was in the the order: Pb > Zn > Ni > Cd. Hence, the road with significantly higher traffic density had notably higher concentration of the metals investigated.[53]

A study was conducted on motorway and National Highway in Pakistan to examine the intensity and outcome of vehicle related metal pollution (Pb^{2+} and Cd^{2+}) on soil and physiological attributes of native plant species i.e., *C. procera, C. ciliaris* and *P. hysterophorus.* Results showed that Pb^{2+} and Cd^{2+} in soil were significantly higher in samples took from along the road as compared with that at 50 m away on both sides of highways. The leaves of *C. ciliaris* along motorway accumulates highest amount of Pb^{2+} and Cd^{2+} whereas, along national highway, leaves of *C. procera* and *P. hyterophorus* had maximum deposition of Pb^{2+} and Cd^{2+}, respectively.[54]

Naser[55] analyzed the concentrations of Pb, Cd and Ni in soils and vegetables along roadside of major highway in Gazipur, Bangladesh. The concentrations of heavy metals (Pb and Ni) in soil and vegetables (bottle gourd and pumpkin) decreased as go away from the road. Cd concentration was observed to be free of distance from road. The general trend for heavy metals concentration both in the soils and vegetables was in the order Ni>Pb>Cd.

Table 1: Relationship between situation, vehicle movement and noise in UK

Situation	Average traffic speed (km/h)	L10 (18hr) index (dB)
Residential road, parallel to busy main road	48	60
18 m from busy main road	48	70
18 m from highway with high volume of heavy vehicles	96	80
3 meter from road in residential area	48	80

An experiment was planned to study the concentrations of Pb, Zn, Cu and Cr at distance ranges from 5-1000 m on the soil of edge of road along Xi'an-Baoji Highway (China). The samples were analyzed to examine contamination levels and determine their spatial distribution. The spatial distribution (mg/kg) of Pb, Zn, Cu and Cr at 5-1000 m distances from the both roadsides (North/South) was in the range of 24 to 38/ 24 to 37, 73 to 122/ 77 to 131, 24 to 42/ 24 to 37, and 64 to 85/ 64 to 86 respectively, at Chencang District section, while at Caijiapo section it was 23 to 46/ 21 to 42, 75 to 135/ 75 to 127, 24 to 36/ 22 to 37 and 64 to 86/ 64 to 88, respectively. The concentration of Pb, Zn, Cu and Cr, were in the range of 25 to 41/ 23 to 33, 74 to 131/ 73 to 118, 24 to 38/ 26 to 45, and 64 to 89/ 62 to 85 respectively at Mei County section.[56]

Noise Nuisance

Vehicle engines, pressure horns and the abrasion between tires and road surface are the main sources of noise from road traffic. Hospitals, playschools and schools are very prone to noise and local air pollution.[57] The relationship between location, traffic speed and sound level in UK[58] has been presented in table 1.

Study was conducted in Canada and it was found that people were highly annoyed by traffic noise. Noise reduces at night (10pm-7am).[59] Daily activities and traffic noise increased exponentially with the road noise exposure. Respondents got concentration problems and hypertension, especially in females (hypertension), unemployed (stress) and people having financial problems (concentration problem).[60] Study was conducted in a municipality of city of Stockholm and found that even at low levels traffic, noise exposure was associated with annoyance and sleep disturbance.[61] Survey was conducted in Sweden and it was found that noise related serious health effects like cardiovascular system was growing besides other issues like annoyance and morning saliva cortisol, hypertension and myocardial infarction.[62] Study was conducted near hospital, educational zones, church and mosque, hotel and recreational zones, offices and working areas, residence and market areas in Dire-Dawa City, Ethiopia. It was observed that noise level in different locations of city was high and crosses the permissible limits. Average values for noise level varies from 45 to 95 dB throughout the study field.[63]

Hearing Deterioration Index, Systolic and Diastolic Blood Pressure were higher among the bus drivers in Puducherry. There was significant positive correlation between Hearing Deterioration Index, service years and exposure level. Prolonged exposure results in deterioration of hearing capacity and high blood pressure problem in bus drivers.[64]

A case study was conducted on Bartin-Karabiik highway in Turkey to assess the noise effects of roads on wildlife using GIS. It was found that highway was risky for wild animals especially for access to the water supply, accidents point and habitat destruction. It was observed that a buffer zone about 350 m down the road and 150 m above the road have higher noise levels than the threshold value.[65]

Remedial measures

To combat pollution due vehicular emissions and its side effects, various methods and technologies have already been quoted in number of research papers but there are no significant outcomes at implementation level. An idea can be applied at local level e.g. plantation of pollution and noise tolerant plant species having high APTI (Air pollution tolerance index) values, which act as buffer[65] to bear air pollution.[66] On the basis of APTI values, plants can be classified as tolerant, intermediate, sensitive and most sensitive species. APTI can act as good remedial measure for green belt development and it also promotes afforestation and reforestation, which ultimately benefits the environment. Planting trees improved the air quality of the area and also enhances the aesthetic and recreational value.[67] Trees also act as sound barrier and useful for providing safety and scenic beauty[68] in hilly terrains. Certain plants called hyper-accumulators, bio accumulate, degrade, or render harmless contaminants in soils water, or air. A range of processes mediated by plants which are useful in treating contamination: Phytoextraction, Phytovolatilization and Phytostabilization. These processes take up, immobilize or remove the toxic chemicals especially heavy metals from soil, water or air and fix them. Plants like Sunflower (*Helianthus annuus*), Chinese Brake fern (*Pteris vittata*), Indian

mustard (*Brassica juncea*), Poplar etc. are useful in fixing toxic chemicals. Though the process is slow but it will give surely promising results.

The generic architecture of decision support systems (DSS) for traffic management contains elements, such as, real-time data; historical data; monitoring; predicting system; strategic analysis. Kantz *et al.,*[69] and Casas *et al.,*[70] showed different methodologies for classifying patterns in the real data and the determining outliers. There are many analytical techniques for prediction of traffic using real data or historical data. Few of them use statistical methods and others use neural networks, fuzzy logic, support vector machines (SVMs). Ruiz *et al.,*[71] and Torday *et al.,*[72] used simulation models with real data for predictive systems with a microscopic or mesoscopic traffic model. Gaynor *et al.,*[73] suggested that the emerging computing model of Dynamic Data-Driven Application Systems (DDDAS) was best-fit during crisis where rapid decision-making was essential. Jan *et al.,*[74] used ArcGIS and Tableau software's to give geo-dynamic decision support system (DSS) for urban traffic management issues to resolve the congestion on the road network.

Almejalli[75] proposed an intelligent traffic control decision support system to help the traffic controller to manage the current traffic state. The results of the case study showed that the proposed system was an effective support for online traffic control. Hoogendoorn[76] have developed a dynamic decision support system based on combining fuzzy logic, case-based reasoning, and multi-agent approaches. The main advantages of the approach were the speed of computation (compared to using traffic flow models), the ability to use actual knowledge directly (rather than general knowledge), and the ability to learn from previous experiences. The system had ability to predict on the impact of different control scenarios to the traffic operations in the network, and thus, supported the operators in their decision tasks in a real-time decision environment. Ossowski[77] has shown how multiagent technology can be successfully applied to build DSS for real-world traffic management problems. They put forward design guidelines for the construction of agent-based DSS, leading to an abstract multiagent architecture. The detailed performance evaluation was carried out in collaboration with the Public Works and Transport Department of the Local Government.

Artificial Neural Network (ANN) was used to study short -term prediction of traffic flow by applying past traffic data. Different parameters viz. traffic volume, speed, density etc. were taken into consideration. Results concluded that ANN has accordant performance for traffic flow predictions even if time interval was changed from 5 to 15 minutes.[78] A study was conducted to predict real time traffic for traffic management. It was observed that different models like analytical model, simulation model and strategic analysis were used to study Decision Support System (DSS) for traffic management on short and medium term prediction.[79]

Kazak[80] conducted a study to observe the possibility of using Community Viz system to create different layouts of assessing public transport in San Sebastian (Spain). Simulating modeling was performed on newly designed housing complex to consolidate the knowledge of local experts.

Conclusions

Road activities are no doubt hugely benefits our society's economy and is backbone of any country's growth and development. In spite of benefits road activities affects and disturb various environmental parameters like air, water, soil, noise etc., and these should be addressed and mitigating measures should be initiated. Technologies like bioremediation, phytoremediation are natural methods to remove contaminants from soil and water. APTI analysis can be done to categorize tolerant plant species so that it can help combating air pollution. Traffic management is big problem even in mountainous region because of tourism factor. Tourism is the big sector on which, economy of any state rely, and with its economic benefit environmental problems are also associated. Limited space and explosion of tourist especially during peak season makes the problem worse. Battery powered vehicles should be encouraged especially in the tourist areas. One of the concerns is how to manage the traffic or road activities so that the effect of vehicular movement on native ecosystems could be reduced. The dynamic decision support system can be used for environmental assessment of road activities.

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Conflict of interest

There is no conflict of interest for this manuscript.

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