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Road Dust Emission Due to Vehicular Traffic- A Review

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Abstract—*Dust generation on paved and unpaved roads is not much attended serious cause of air pollution. The presence of dust reduces visibility and poses an overall hazard to health and safety of road users. In India, it is customary to subject WBM road for traffic prior to its asphalting for some duration. During the maintenance of even asphalted roads, there is a practice to fill the pot holes by murum or similar locally available material. WBM surface and pot holes are major sources for dust emission. The emitted dust consists of range of particulate, majority of which remains suspended in the atmosphere. The abatement of respirable content is essential to protect human health as well as plant life. In India such efforts are not taken. In developed countries many researchers have contributed to study dust generation by vehicle on paved and unpaved road surface in spite of having better quality of roads as compared to Indian situation. Many efforts lead to develop relationship between nature of vehicle and dust emission. A few researchers have also deduced procedures to measure and characterize emitted dust on a real-time basis by involving high end instrumentation. In general the efforts are significant to minimize the ill effects of dust emission on plant, animal, and human life. It would be helpful to have review of the work done in developed countries and apply the results to improvise Indian road construction and maintenance practices. The study will also create many research avenues in the road construction industry in light of air pollution.*

1. INTRODUCTION

India's road network is gigantic and has a total of about 4.6 million kilometers of roads out of which 2.1 million kilometers are surfaced roads and about 2.6 million kilometers of roads in India are the poorly constructed ones [7]. Roads indirectly contribute to the economic growth of the country. It is extremely essential that the roads are well laid out and strong but one of the striking underlying facts is the condition of the roads. India is home to several bad roads, be it the metropolitans, the cities or the villages. On the other hand traffic is one common problem in most of the cities. This is mainly because of industrialization and the sudden rise in vehicle ownership over the last few years.

The amount of dust generated and its resettling on the road surface depends on various factors such as traffic speed, vehicle weight, local road conditions and rainfall. The strength and direction of the wind is a highly influential factor on its transportation [6]. The coarser fraction has local road safety, agricultural and environmental impacts on travellers and on residents near unpaved roads. The finer fraction can be transported more widely with potentially highly damaging impacts to health. The visible very coarse fraction that resettles on the road surface is then also subjected to grinding and regrinding by traffic to produce the fine particles.

In India road maintenance is done by traditional methods. In this method bituminous roads are treated as WBM road and road damage like potholes, edge cracking etc. are recovered with the help of murum or locally available suitable material. Unpaved roads provide an almost inexhaustible supply of dust. The surface of unpaved roads is disturbed regularly so that dust particles are entrained into the air by every passing vehicle. The action of the vehicles wheels also pulverize the road material into ever decreasing particle sizes so that dust of all sizes is continually being produced, including the potentially dangerous PM10 and PM2.5 fractions [6].

A vehicle travels on unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents. The turbulent wake of the vehicle continues to act on the road surface after the vehicle has passed. On paved roads dust, which is often contaminated by fuel products and other pollutants are continually disturbed and made airborne. On unpaved roads, high volumes of surfacing material are available to be transported into the air as dust clouds and these may also contain other airborne pollutants. High vehicle speed is an important factor in generating dust due to the increased transfer of energy disturbing the dust from the surface of the road and the greater turbulence which transfers a greater amount of dust into the air.

Dust generation by vehicles on paved and unpaved roads can cause serious air pollution, reduce visibility and the safety of motorists, pedestrians and workers and pose an overall hazard to health. The abatement of respirable content is essential to protect human health as well as plant life. In India such efforts are not taken. In developed countries many researchers have contributed to study dust generation by vehicle on paved and unpaved road surface in spite of having better quality of roads as compared to Indian situation. Therefore the aim of this work is to review various works done by researchers for the abatement of road dust emission essentially due to vehicular traffic.

2. REVIEW OF PREVIOUS WORK DONE

Many researchers have contributed in this study area over the world. For convenience their work is divided in following categories and its review is taken in forgoing paragraphs.

3. EXPERIMENTAL ROAD DUST MEASUREMENT DEVICE

A few scientists have attempted to devise a suitable device for experimental road dust measurement device [5]. In one of the studies an attempt has been made to develop a device to measure the dust production from the test sections for a vehicle on a real-time basis. The device named as dustometer was used, which is basically a moving dust sampler, consist of a standard high volumetric sampler with associated filter media and accessories mounted on the rear of a pickup truck (see Fig. 1). The device is designed to allow for easy removal and replacement of the filter paper.

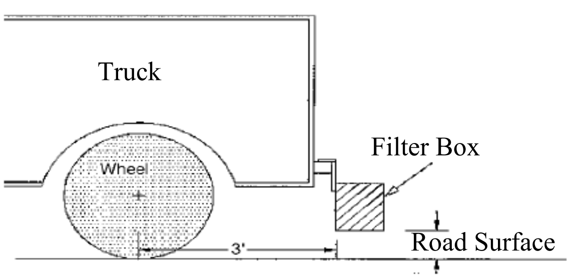

Fig. 1 Schematic of Dustometer attached to truck

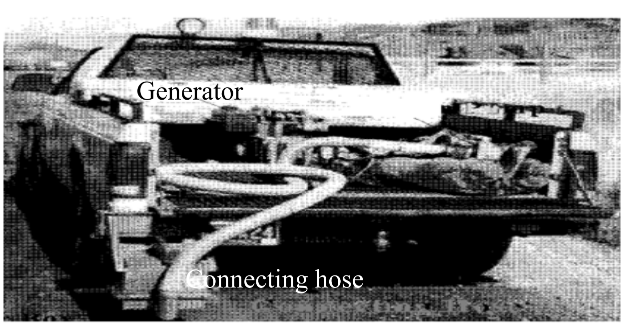

Fig. 2: Rear view of test truck

This device consists of the flexible hose connecting the suction pump to the filter (see Fig. 2). During each test run the generator is started, and the truck is driven at a stipulated speed. At the beginning of the 1-mile mark when the truck is moving at the desired speed, the pump is turned on and a portion of the dust kicked up by the rear left tire is drawn into the filter. At the end of the 1-mile run the pump is turned off, and the vehicle is then brought to a stop. The dust laden filters were carefully removed from the filter box after every run, placed in pre weighed plastic bags, taken to the laboratory, and weighed. To demonstrate the precision of the dustometer as an experimental road dust measurement device, nine replicate measurements were taken on the 1-mile untreated test section at different speeds. From this study they concluded that there is linear relationship between the speed and amount of dust generation and approximately 2.3 gm of dust were measured at a speed of 20 mile/hr, and about 7.3 gm were measured at 50 mile/hr.

4. DESIGN OF DUST COLLECTOR FOR FOUR-WHEELER

A few scientists have attempted to conduct the study on design of dust collector for four- wheeler [1]. In this, work is aimed to design a dust collector system for high clearance four-wheelers to minimize the level of non-exhaust emissions to some extent. This model consists a centrifugal fan which is connected to a 200W motor which is connected to battery of 12volt i.e. car battery (see Fig. 3). This battery runs our motor and hence results in rotation of motor at 600rpm, which turn the fan impeller at the same rpm. This rotation of impeller creates suction in the nozzle attached to the centrifugal fan inlet opening, this suction in the hose or nozzle would be enough for the dust to get sucked in through the hose and then passes through fan outlet opening. Then the fugitive dust passing through the connecter filters the air and deposits the dust in collector. This tank can store around 1.2kg of PM10 particles which is enough for 500kms, and then this storage tank needs to be cleaned by opening the led and collecting the dust in plastic bag.

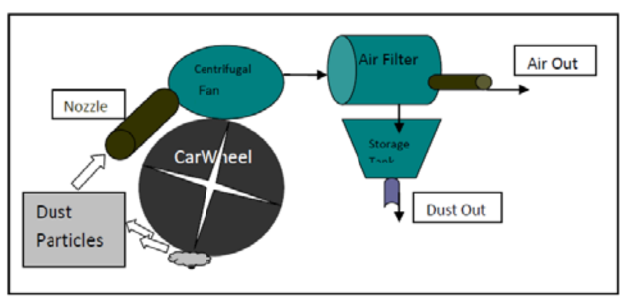

Fig. 3: Design of Dust collector system

5. EFFECT OF VEHICLE CHARACTERISTICS ON UNPAVED ROAD DUST EMISSIONS

A few scientists have attempted the study on effect of vehicle characteristics on unpaved road dust emissions to measure emissions from vehicles and characterize their wakes and injection height of dust plume [2]. For this a mix of civilian and military vehicles covering a substantial range of weights, length and width dimensions, and number of wheels were used to understand how these properties relate to emissions of dust, specifically the PM10 component. Vertical profile measurements of mass concentration of the passing plumes were carried out using a series of three instrumented towers. Three towers were set up collinearly and perpendicular to a 1000m section of unpaved road and all downwind of the road at distances of 7, 50, and 100m (see Fig. 4). Each downwind tower was instrumented with four DustTraks configured to measure PM10 that were spaced logarithmically in the vertical direction.

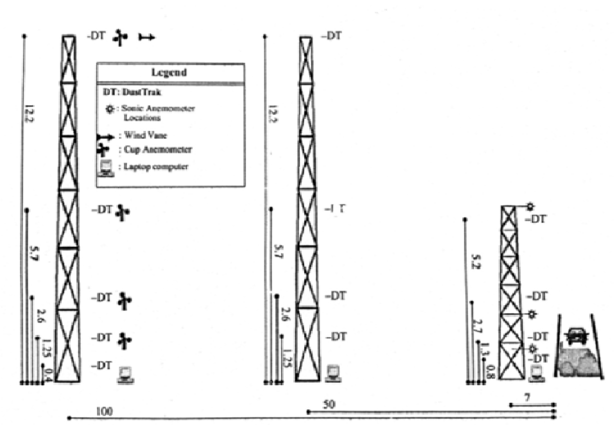

Fig. 4: Schematic diagram of the 3-tower dust monitoring system. Units are shown in meters.

The DustTrak is a portable, battery operated, laser-photometer that uses light scattering technology to determine mass concentration of dust in real-time. Five anemometers, one windvane, and one temperature probe were mounted on DustTraks in order to characterize the local meteorological conditions. Dust concentration and meteorological data were collected and stored on PCs located at each tower. Road dust PM10 emissions were created by having a test vehicle travel back and forth along the roadway for a number of passes. After passing of vehicle PM 10 emission fluxes at each tower were calculated from knowledge of the vertical mass concentration profile, the ambient wind speed and direction, and the time the plume took to pass the towers. From this study, the emission factor is linearly depends upon on speed and vehicle weight. Emission factors (EF = grams of PM10 emitted per vehicle kilometres travelled) ranged from approximately EF = 0.8 × (km/hr) for a light (1,200 kg) passenger car to EF = 48 × (km /hr) for large military vehicles (18,000 kg). This suggests that emissions are linearly dependent on a vehicle's momentum. Other physical characteristics of the vehicles (e.g., number of wheels, undercarriage, area, height) did not appear to heavily influence the emissions. The size of a wake created by a vehicle was observed to be dependent on the size of the vehicle, increasing roughly linearly with vehicle height.

6. VEHICLE-BASED METHOD FOR MEASURING ROAD DUST EMISSIONS

A few scientists have attempted to conduct the study on vehicle-based method for measuring road dust emissions [4]. TRAKER (Testing Re-entered Aerosol Kinetic Emissions from Roads) which is a vehicle-based method for measuring road dust emissions. Particulate matter is sampled in front and behind a vehicles tire and the difference in PM concentration (TRAKER signal) is used to infer the airborne flux of particles from the roadway. The concentration of airborne particles is monitored through inlets that are mounted near the front tires of a vehicle. These particle sensors are influenced by the road dust generated from the contact of the tire with the road. A background measurement of particle concentrations is obtained simultaneously at a location on the vehicle farther away from the tires. The difference in the signals between the influence monitors and the background monitor is related to the amount of road dust generated. From this study two independent tests indicated that the TRAKER signal increases as the cube of the speed for a road dust loading. Simultaneous measurement of PM10 dust emitted behind the tires by TRAKER with PM10 flux measured using upwind/downwind towers suggested that the emissions factor for road dust was proportional to the cube root of the TRAKER signal. The results also showed a linear relationship between distance based unpaved road dust emission, PM10 emission factors, and vehicle speed.

7. ESTIMATION OF ROAD DUST USING BIG SPRING NUMBER EIGHT (BSNE)

A few scientists have attempted to device a procedure to estimate road dust using BSNEs [3]. The sampler was used to measure the dust emitted by vehicle. BSNE sampler has a relative large inlet area of 10 cm^2. The measurements were carried out on two unpaved roads in Lulea situated in Sweden. The car used for dust generation is Ford Mondeo with an approximate weight of 1730 kg and 4 wheels. The car drove for 15 runs with different speeds. BSNE samplers were installed at the heights of 0.25 m, 0.50 m, 0.75 m and 1.00 m down wind direction on the road. Two sets of BSNE samplers were installed at the same side of the road in order to collect adequate dust quantity and the background dust was assumed to be zero. Besides the BSNE samplers, two weather stations were installed at the height of 1 m and 2 m. The measurements were done on the road sections which were perpendicular in the wind direction to ensure the largest amount of dust to be obtained in the samplers. The dust in the samplers was collected by a brush with a great care to avoid sample loss. All the samples were weighed in the lab by a balance with the precision of 0.0001 g. The sample of surface material from the road was collected and tested for moisture content and particle size analysis. From this study it is concluded that the dust mass is highest at the lowest height and decreases with increasing height reaching zero at the top of the dust plume. It is reasonable to assume the zero dust mass to the ground surface level, which means the dust emission increasing sharply to the maximum value at a small height of near the surface. The dust mass collected in sampler is then divided by the inlet area of BSNE samplers to calculate the dust amount per square meter at the four measuring heights. It is also indicated that there is a strong relationship between vehicle speed and dust emission. Soil texture and the moisture content of the surface materials from the two roads were tested. The second road has a higher amount of fine grains with size below 63 μm than that of the first road. Soil texture is the most important soil factor influencing dust production. With finer fraction existing the more dust can be generated.

8. DISCUSSION

It can be seen from various contributions made in above mentioned paragraphs that, many researchers have identified the issues related with road dust emission in different ways. The major findings are as follows, the speed of vehicle and weight of vehicle are the major influencing factor for dust emission. Physical characteristics of the vehicles such as shape and number of tires and tread pattern may have minor influence on the emissions. The moisture content and the soil texture of the surface material is the most important soil factor influencing dust production. With finer fraction existing the more dust can be generated. In this context the study in relation with road dust emission is relevant.

9. CONCLUSION

In India any of such works haven't dealt with so far, the issue of road dust emission is handled by various researchers mostly at developed countries. Having absence of such studies for Indian conditions there is scope for the study. It would be helpful to have review of the work done in developed countries and apply the results to improvise Indian road construction and maintenance practices. The study will also create many research avenues in the road construction industry in light of air pollution.

10. ACKNOWLEDGEMENT

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