Theoretical Study on Generation and Characteristics of Dust and its Dispersion Mechanism

Mrs. A Theerkadharshini[1], S Vignesh[2], D Purushothaman[3], S Sivaprakash[4], S Vignesh[5]

[1]Associate Professor, Department of Civil Engineering, Panimalar Engineering College, Chennai
[2,3,4,5]UG Student, Department of Civil Engineering, Panimalar Engineering College, Chennai

---***---

Abstract— *Dust is an important component that people come across everyday while travelling. The dust that gets collected along the median has got significant properties which vary from region to region. This dust when left unattended may cause serious air pollution problems which in turn results in health problems. A theoretical study of the characteristics of dust collected along the median across different regions will help understand the nature of dust and its harmful effects which in turn can help in framing better means to control the same.*

Keywords— **sources, combustion, mechanism, dispersal, vehicles**

1. INTRODUCTION

Dust is fine particles of solid matter. It generally consists of particles in the atmosphere that comes from various sources such as soil, dust lifted by wind (an Aeolian process), volcanic eruptions, and pollution. Atmospheric or wind-borne fugitive dust, also known as Aeolian dust, comes from arid and dry regions where high velocity winds are able to remove mostly silt-sized material, deflating susceptible surfaces. This includes areas where grazing, ploughing, vehicle use, and other human activities have further destabilized the land, though not all source areas have been largely affected by anthropogenic impacts. Dust kicked up by vehicles travelling on roads may make up 33% of air pollution. Road dust consists of deposits of vehicle exhausts and industrial exhausts, particles from tire and brake wear, dust from paved roads or potholes, and dust from construction sites. Road dust may be suppressed by mechanical methods like street sweeper vehicles equipped with vacuum cleaners, vegetable oil sprays, or with water sprayers. Improvements in automotive engineering have reduced the amount of PM10s produced by road traffic; the proportion representing re-suspension of existing particulates has increased as a result. Dust originates from multiple sources, including dry animal skin, hair, faeces, and feed particles. Its behaviour is influenced by many environmental factors, including air temperature, humidity, flow rate, type and amount of feed provided and animal activity level. For people living in developed countries, road dust was primarily considered to be a nuisance. Only relatively recently has it gained greater prominence as a potentially serious polluting agent. However, whilst travellers along unpaved roads in these countries are obviously inconvenienced by dust and may also suffer health and road safety risks, these impacts tend to be relatively minor compared those experienced by residents and travellers in developing countries. In high income countries, relatively few people live as close to unpaved roads as do residents in developing countries and road travellers are far less exposed, travelling as most do, in air conditioned vehicles or vehicles in which dust and other airborne agents are filtered out by ventilation systems. However, even in these countries, the problem is of sufficient concern for its impacts to be investigated, although there is also the additional driving factor of the commercial interest of the dust control industry and these two factors combined have resulted in the establishment of an annual conference in the USA on Road Dust Management. Studies by the EPA in the USA have also shown that dust emissions from unpaved roads are significantly reduced by daily rainfall of 0.01inch. Studies in New Zealand in the 1980's also indicated the extent to which road dust was affected by rainfall. However, many tropical countries experience their highest temperatures in the rainy season. In these conditions, road surfaces dry quickly and dust again becomes problem after just a day or so without rainfall. In developing countries, road users in rural areas and poor urban areas predominantly comprise pedestrians, pedal cyclists, motor cyclists, users of motor-cycle-drawn taxis and users of other non-motorized vehicles (e.g. ox and donkey carts, hand-drawn carts, etc). These road users, who regularly walk or travel in open vehicles, will, in general, have a much higher frequency and degree of exposure to dust than users of unpaved roads in developed countries. People travelling in motorized transport in these countries often travel in the open in the back of vehicles such as 'pick-ups' or conventional trucks and are particularly exposed to dust generated both by the vehicle in which they are travelling and by other vehicles. Very few public transport services in developing countries are air-conditioned and ventilation is provided by open windows so that even people travelling in vehicles that may normally be considered to be enclosed are also exposed to dust. In rural areas of these countries, few people own their own vehicles so there is a natural tendency to build houses near roads which gives them access to passing trade and shorter journeys to markets and access to transport and other essential services. For much of the year, these dwellings and their occupants are almost constantly exposed to traffic-generated dust. In urban areas too, it is often the poorest of the poor who are most affected as they tend to dwell in houses close to the road, often in informal settlements, and thus live and travel in areas where dust from unpaved roads and other potentially damaging pollutants are often most prevalent. In these areas, long-term exposure to the effects of Total Suspended Particulate (TSP) pollution, including road dust, may pose a serious health risk to all inhabitants and particularly to children and the elderly.

2. PHYSICAL CHARACTERISTICS

A. Particles Sizes and Size Distribution

Size is characterized by particle diameter, or for irregular shapes - equivalent particle diameter, i.e. the diameter of a sphere having the same value of a physical property as the particle being measured. Equivalent diameter relates to any property, e.g. inertia, electrical or magnetic mobility, light scattering, radioactivity, Brownian motion, or to chemical or elemental concentration, cross-sectional area, and volume to surface ratio.

B. Elemental Composition

Combustion results in emissions of a cluster of different trace elements, present in the fuel or the lubricants used (motor vehicles). Since most trace elements are associated with ultra fine particles and are less prone to chemical transformations, they undergo long-range atmospheric transport. Mechanical processes, such as mining, mineral processing, quarrying, breaking, grinding, dust re-suspension, etc, generate particles predominantly containing crustal elements.

3. SOURCES OF DUST

Sources of this dust, which are sometimes also referred to as non-point sources, include construction sites and agricultural land and paved and unpaved roads. Consequently, small amounts of dust are nearly always present in the atmosphere, especially in areas where the climate is dry and vegetation is sparse. Drought conditions and poor land-use practices in these areas can exacerbate the problem and in extreme situations can cause 'dust bowl' conditions. Concern over the impacts associated with this event contributed to a major revision in agricultural practices in these areas of the country. Equations such as the one below (1) have been developed to help estimate the volume of dust generated from unpaved roads.

$$E = [2.6\{(s/12)0.8(W/3)0.4\}/\{M/0.2\}0.3\}] \times 0.2819 \quad (1)$$

Where E = emission factor in kg/vehicle km
s = silt content (% surface material < 0.075mm)
W = average vehicle weight in tonnes
M = surface material moisture content (%)
There has been some criticism in the literature of its applicability in all circumstances, which is not surprising given the complexity of the mechanisms governing the production of road dust but it is still thought to give a good reflection, empirically, of the factors influencing the production of traffic-generated dust. Sources of PM include cars, trucks, buses, factories, construction sites, tilled fields, unpaved roads, fires, natural windblown dust and desert areas. The amounts of fugitive dust present in the air is usually classified in two main size fractions, namely PM10 and PM2,5 with aerodynamic diameters less than 10μm and 2.5 μm respectively. To give a comparative indication of size, the PM10 fraction (i.e. from 2.5μm to 10 μm) is about one seventh the diameter of a human hair and is referred to as the coarse fraction. The PM2.5 fraction is referred to as the fine fraction. Both the PM10 and PM2.5 fractions are invisible to the naked eye. The very coarse fractions larger than these are particularly evident in traffic-generated dust.
The amount of this dust that is generated and then re-settles on the road surface depends on various factors including traffic speed, vehicle weight, local road conditions and rainfall. The strength and direction of the wind is a highly influential factor on its transportation. 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 as discussed later in this report. The visible very coarse fraction that re-settles on the road surface is then also subjected to grinding and re-grinding by traffic to produce the coarse and fine particles as defined above. 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. Sizes are continually being produced, including the potentially dangerous PM10 and PM2.5 fractions. Vehicle movement is one of the main dust-producing activities in the road sector. The shearing action by the tyres on the road surface creates loose material that is then transported into the air by the turbulence caused by the movement of the vehicle. This action is present on both paved and unpaved roads. 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 air-borne 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.

4. MECHANISM BREAKDOWN

Dusts usually originate from larger masses of the same material, through a mechanical breakdown process such as grinding, cutting, drilling, crushing, explosion, or strong friction between certain materials (e.g., rocks). Dust thus generated is often called "primary airborne dust." The composition of mineral dusts is not necessarily the same as that of the parent rock since different minerals may break down or be removed at different rates. Vegetable dusts can originate in the same manner from a work process, for example: wood dusts produced in sawing and sanding, cotton dust in ginning, carding and spinning operations, and wool dust in shearing sheep. The rate of dust generation increases with the energy associated with the process in question. For example, a grinding wheel will produce more dust when it operates at higher speeds. Although friability, that is ability to be broken down, is another important characteristic, more friable does not necessarily mean more hazardous; for example, very hard quartz, once submitted to strong enough forces that break it down to microscopic sizes, is a much more serious health hazard than the more friable marble.

5. DUST DISPERSAL

Instead of resulting directly from the breakage of a bulk material, airborne dust may arise from dispersal of materials in powder or granular form. Dust is released whenever processes involve free falling or handling of such materials, e.g., transferring, dumping, filling (bagging) or emptying bags or other containers, dropping material from a hopper to a weighing station, weighing, mixing, conveying and so on. Moreover, air currents over powdered materials may be important. These mechanisms not only release dust, they also generate it, because smaller particles may be formed from larger ones by impaction and friction. The particle size distribution of a dust cloud may be different from that of the powder it originated from; this should be investigated for each situation, as it depends on the type of material and on the forces it underwent during its handling or processing.

6. HEALTH EFFECTS DUE TO DUST

CONCRETE DUST: When working with concrete, silica dust becomes airborne and can potentially be toxic. Exposure to silica dust can lead to silicosis, a disease caused by breathing in too much of the crystalline silica found in dust. These fine particles can lead to the thickening or scarring of the lungs, and ultimately cause lung cancer.

WOOD DUST: Also known as sawdust, wood dust is a result of manipulating wood. Be it by sanding, grinding, drilling, or cutting, fine particles of wood are released into the air, forming a layer of dust once settled. Wood dust can be dangerous when airborne and inhaled. It could potentially cause allergic reactions, issuewith the oral mucous membrane, or cancer, though the extent of these risks has not been fully established.

METAL DUST: Metal dust is typically formed by grinding metal during the process of drilling. Workers exposed to metal dust can experience irritation in the lungs and throat. Certain types of metal dust can be extremely toxic, particularly if the metal is comprised of heavy metals like cobalt, lead, or nickel. It is important to wear some type of respirator when working with metal to prevent harm to lungs.

MINERAL DUST: Mineral dust is atmospheric aerosols originated from the suspension of minerals constituting the soil. It is composed of various oxides and carbonates. Human activities lead to 30% of the dust load in the atmosphere.

AIRBORNE DUST: is particle, or Particulate Matter (PM), pollution, and is one of the most significant air pollutants in Pima County. PM is made up of tiny solid particles or liquid droplets (a fraction of the thickness of a human hair) that float in the air we breathe.

7. DUST CONTROL

Dust control can be achieved either by better selection of materials, mechanical stabilisation using two or more different materials to achieve a better particle size distribution and to increase or reduce the plasticity or by applying a chemical dust palliative. In terms of the total unsealed road network, minimal dust control is currently being carried out, despite better material selection criteria being available. The last few years have also seen a proliferation of dust palliatives which the manufacturers claim will reduce both dust and maintenance on unsealed roads. However, minimal specification of their properties or records of their performance have been made available and very few properly controlled comparative tests on the effectiveness of the products from different producers and suppliers were carried out in full-scale field trials.

8. CONCLUSION

In order to decrease dust emissions from such operations, it is important to understand the mechanisms of its generation and release. Studies on dust generation by free falling powders have demonstrated that the manner in which the powder is handled may be as important as the dust generating capacity of the bulk material, in terms of the resulting exposure. Falling height has an important influence on dust generation and release for more than one reason. The higher the impact, the more dissemination of dust there is. Moreover, the greater the falling height, the greater flow of entrained air, which favours dust dissemination. This shows the importance of process design and adequate work practices. Hence an appropriate means considering all the above mentioned factors have to be invented so as to reduce the impact caused by dust on both the environment and on health.

REFERENCES

[1] A. Buekens, "Dust – Particle formation and Characteristics," CHIS 2, Vrije Universities Brussel, Belgium.

[2] Augus Noble Thomas, Vinu Paul, Amritha Joy, Rexmi John "Design and Fabrication of Metallic-Dust Collector in Chainsaw Sharpeners," SSRG International Journal of Mechanical Engineering (SSRG - IJME) – Volume 5 Issue 9 – September 2018.

[3] Tony Greening, "QUANTIFYING THE IMPACTS OF VEHICLE-GENERATED DUST: A COMPREHENSIVE APPROACH," Department of International Development.

[4] Shubham Thakur, Rakshit Jain, Anurag Johari, "Roadside Dust Cleaning System" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 04 Issue: 12 | Dec-2017.

[5] National Air Pollutant Emission Trends, 1900 - 1995. 1996. Research Triangle Park, NC: Office of Air Quality Planning & Standards, US Environmental Protection Agency.

[6] Compilation of air pollutant emission factors, Vol 1: Stationary point and area sources. 1996. Washington, DC: Office of Air Quality Planning and Standards, US Environmental Protection Agency.

[7] McCREA, P.R. 1984. An assessment of the effects of road dust on agricultural production systems. Lincoln College, New Zealand: Agricultural Economics Research Unit. (Research Report No 156).

[8] The structural design, construction and maintenance of unpaved roads. 1990. Pretoria: Committee of State Road Authorities. Department of Transport. (Technical Recommendations for Highways; TRH 20).