DUST EMISSION ON UNPAVED ROAD SURFACES DUE TO VEHICLE EFFECTS

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DEDICATION

This project is dedicated to my parents Mr. and Mrs. Olom and to all my brothers and sisters who are always by my side in all situations.

CERTIFICATION

This is to certify that this project, was carried out by **Olom Paul Agbor** in the Department of Agricultural Engineering, Federal University of Technology, Minna.

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Above all, to God be the highest glory in every thing, especially for being what He is to me and us at all times.

ABSTRACT

This project is a study of the rate of loss of airborne fine materials dispersed from unpaved farm, rural/feeder roads in minna relative to vehicle characteristics and interaction on unbound road surface. Five different vehicles subjected to same conditions generate varying amount of dust particles ranging between 0.83g – 4.68g after three passes on a 100m unpaved minna – sheta road. To generate this dust, the five vehicles were individually made to run across the given road section at varying speed limit while other factors were constant. Result from suitable road/soil test and analysis showed that particles collected ranges between 0.095mm – 5mm in size, plastic limit of 16.5%, liquid limit of 45.3% and plastic index of 28.8%. The plasticity index of the dust particles is higher than the suitable range of 19-25%. The soils therefore are prone to erosion and cracking of road surfaces. The dust collected also showed that emission is a function of vehicle characteristics. Measure employed to stop and control dust include the use of heavy road construction and stabilizing machines. Certain chemicals like waste sulphur and local material like palm oil are also used as dust palliative. Unpaved roads should be highly stabilized and or paved.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Introduction

Dust emission on unpaved road surfaces has been on global warming and dates back a number of centuries. This problem has grown to an alarming stage and not more a phenomenon as a result of vehicles interference with unpaved roads especially in the present times.

The dust emission has imposed a menace to many aspects of the economy and the well being of man. The areas mostly affected include the agricultural production, environmental and health sectors. More serious effects recorded in developing countries such as Nigeria where farm roads, rural and feeder roads are unpaved where as they have high traffic influx per day.

The unpaved roads constitute a high percentage of farm, feeder and rural road network in Nigeria where food, agricultural raw materials and other industrial raw materials, are collected. However, these routes are mostly neglected and as such are associated with dust, traffic accidents, high cost of vehicle maintenance.

It therefore becomes important to give special attention and consideration to these unpaved roads and dust emission associated with them in order to enhance high agricultural and industrial production, avoid environmental pollution and generally check dust effects as recorded on global warning and finally live in a dust free world.

This research identifies the sources and causes of dust, quantifies the amount emitted per vehicle characteristic and finally suggests and indicates possible solutions to tackle this problem.

1.2 Dust

Dust is a finely powdered and minute earth particle of mineral and or plant materials lying on the ground surface, on the surface of other materials and some are suspended in the atmosphere and carried by wind. The major sources / constituents include natural soil particle, automobile exhaust emissions, tyre wear, metal from corrosion (of metal parts), cement particles from building of these, soil is about 77% of dust.

1.3 Unpaved Roads

Unpaved roads is an integral part of functional roads. It belongs to earth road which foundation and wearing surfaces are composed of natural soil along the alignment of the road. There are two types viz. the ordinary and the stabilized earth roads.

During the dry season and in dry areas, these roads are affected and generate a high amount of dust particle as a result of vehicle interaction on the unbound surfaces of the road. In addition to the traffic effect, dust is also generated by the climatic influence of wind and rain fall.

Analysis shows that unpaved roads traffics produce about 35% of the atmospheric pollution worldwide. Of this, 28% is from dust while 7% is from the exhaust gas respectively.

As a result of dust emission, unpaved road are a traffic and maintenance menace and are quite risky to travel by. The dust emitted on these roads surface reduces visibility and vehicle efficiency along side increasing environmental and health problems.

In addition, unpaved roads are easily eroded in the wet season, are very slippery and impose a greater danger to user and some cases dislink users leading to a greater level of economic imbalance, damage and spoilage of agricultural and industrial raw materials and generally lead to abject poverty since about 70% of Nigeria's total population is found in the rural areas.

1.4 Loss Of Materials

The loss of materials from the unpaved road surfaces is mainly as a result of non-availability of selected and processed material to bind the soil and other dust constituent on the road surfaces together, as well as the non-redistribution of the applied vehicle load. Then makes the road materials structure loose and less cohesive.

The emission of the fine particles from the road surfaces arises from the loosening of the soil structure and a reduction in the cohesion of the gravel wearing caused by the action of traffic and climate. The lost materials increase the permeability of the surface layer and results in the early development of the pot-holes, all of which accelerates the need for regravelling. The coarse surface texture brought by the removal of the finer fraction often leads to higher levels of surface irregularities which lead to increase in vehicle operating cost, dust emission, traffic accident, environmental and related hazardous effects.

However, the vehicle characteristics interacting on the road surfaces that affect loss of materials depends on the nature of the soil material on a given road and these include:

i) Soils being heterogeneous, that is their materials or engineering properties vary widely from point to point within a soil mass.

ii) Soils being inentropic, that is their engineering properties are not the same in all directions.

iii) Soils being non-linear, that is their stress-strain curves are not straight lines.

iv) Soils being not conservative, that is they respond to almost everything that happens to them.

v) Soils in-situ in the field is characterized by joints, fractures weak layers and other defects in the material.

Base on the above soil engineering characteristics, different sections of the road will experience different effect of the vehicle characteristics and as such produce varying amount of dust even if other factors are kept constant.

1.5 Dust Problems

The dust problems as identified in this research are mainly a general traffic and safety problem, environmental and health menace. Agricultural and industrial production set back, all of which lead to low standard of the national economy.

Dust obscure visibility leading to many traffic accidents. Dust particles that settle on crops add to processing cost, make crops unattractive and reduce their economic and market values and a danger as a food source. Dust in living homes cause chest pains, cough, eye and nasal irritation and excess death of 4000 persons usually worldwide. Dust increase cost of maintenance and operation of vehicles, farm equipment, machines and buildings.

Hence, dust need to be eradicated as it affect life negatively in every aspects.

1.6 Road Safety

Unpaved roads generally are very unsafe since they are prone to traffic accidents. Over the years they have recorded a higher accident rate per kilometer than paved roads.

Observers in the U.S.A claim that 230% more people are killed on unpaved roads per vehicle kilometer as compared to paved roads and this is due to visibility and to skidding.

In Nigeria with reference to Niger State, as a result of reduction in visibility in the dry seasons, slipperiness of unpaved roads in the wet and the poor geometric standard of the unpaved roads, the traffic accident has risen and about 155 persons die annually and about 253 are injured from the roads. This however could be under estimated since not all traffic accidents on these roads are reported and recorded (Federal road Safety Research 2000).

1.7 Aims And Objectives Of The Research

This project is strictly concerned with the long term implication of dust problems associated with unpaved roads:- farm feeder, rural and even urban roads in Niger State, Nigeria.

i. To investigate the causes, sources and general problems associated with dust from unpaved road surfaces.

ii. To quantify the amount of dust particles generated on a given road interacted by a vehicle of specific characteristics.

iii. To suggest and find possible solutions to the problem of dust on unpaved road.

1.8 Scope Of The Study

A section of an unpaved road leading from the Julius Berger's contraction company to Shetta village in Minna was chosen to demonstrate vehicle interaction on unpaved road giving rise to dust emission and other effects.

This section of the road chosen depicts the nature of farm, rural and feeder roads network in this district. The road is unpaved and thus consist mainly of natural earth materials.

Other key equipments and instrument used to aid successful experimentation include; thick paper of A1 size, measuring tape, pins, anemometer, wind vane, hygrometer and thermometer.

On the other hand the standard vehicles that were subjected to pass on this road section include a Peugeot 505 car, Toyota Corola car, Mitsubishi bus, Nissan truck and the tractor.

Samples of fine particles collected at each run of the different vehicles are given in table II of the result.

The fine particles were collected on the thick paper and the fine particles collected were weighed, size distribution determined, moisture content and their plasticity index were also determined as shown on the result. The wind vane and the anemometer and all other necessary equipment to determine the environmental factors were fixed at adjacent positions to the papers for collecting fine particles.

All values measured and or determined are clearly shown on the result section.

CHAPTER TWO

2.0 LITERATURE REVIEW

There is a great deal of experimental evidence to suggest a link between dust particle emission on unpaved roads surfaces and the vehicle characteristics effects.

However, there have been few attempts in the pastto determine accurately the amount of air borne fine dislodged by traffic on unpaved surfaces.

Lorbor and Lankmayor, (1966) reported that 50grams of fine particles can be disloged per square meter of filter surface. Later, Leroux and Powers (1969) confirmed same quantification of emission of fine particles on unpaved roads. They carried their experiments using a model A.D.G Toshiba X-ray diffraction spectrometer together with a Toshiba strip chant recorder.

Again , Natushch (1972) showed that the bag house smelting of iron could generate 743grams of dust.

Robert et al (1980) in the U.S.A found that on gravel roads each vehicle kilometer run at a traffic speed of 32km/h contributed to 2.0kg of fine mantras to the air, equivalent to 73 tonnes per kilometer per year. Schemel in the U.S.A did same work and showed that even paved roads in rural areas could contribute 8 tonnes per kilometers per year for vehicles traveling at 32km/h.

In both cases, the dust emission was proved to vary as an exponent of the speed. Further research by Roberts et al (1980) showed that the emission rates on gravel roads varied with the particle size distribution of the wearing coarse material and the size and type of vehicles.

Jones (1984) carried out a related research n Kenya and in the U.S.A and the results from the findings and samples taken indicated that on unpaved roads carrying 100 vehicles per day and traveling at 75km/h up to 25tonnes can be lost annually per kilometer.

In attempt to measure and quantify the amount of fine particle emission Hampden (1997) in Las Vegas shows that the sensor positioned behind the front tyre of a vehicle, to measure dust, recorded that 20 tonnes of fine particle is lost annually n vehicles speed of 65km/h. Still Etyemezian (1977) a DRI air quality scientist in collaboration with the Naveda Department of motor vehicles, using a Dopier SODAR on the roof of Palo Verde High school identified that dust emission on unpaved roads is dependent on the vehicle characteristics alongside other environmental effect and factors.

The Mid west Research Institute (MRI) (1998) identified dust as being on a greater proportion. They claimed about 45% of the pollution result from dust. The US Environmental Protection Agency (US EPA) in collaboration with the National/Ambient Air Quantity Standards proved that dust caused by vehicles and environment of the society at a great menace. According to their resent findings and survey data, unpaved roads accounts for 28% of the nationwide dust formerly known as PM-10 (dust particles 10 microns or less). This however is redefined to mean and give a PM-2.5 standards.

Recent research by FEPA Nigeria reveals that emission of particles is dependent on how much silt a road surface is contained.

Base on all these research and findings, similar solutions are suggested and requited to reduce and check particle emission especially on unpaved roads. The key suggested solution for the remedial treatment include use of bituminous seals, coating with deliquescent salts, application of water and waste sulphur etc.

Generally dust particle emission in unpaved roads had been analyzed from different point of views and with different background of understanding. This research and the report concentrates and relates the emission with the effect of vehicle characteristic interaction on the unpaved road surfaces.

The research also takes into account at the same time effects of climatic, environmental, soil and vehicle characteristics leading to emission of fine particle on any given unpaved road section.

To achieve the stated and implied objectives and aims, research was made across different fields of studies such as; the Road Transport Corporation,, the Environmental protection Agency, Road and other

Construction companies, the chemistry of environment, the soil science and soil mechanics, the health and medical studies etc.

Effort in these areas were intensified to finding and studying specific effects and problems and dust from unpaved road surfaces due to vehicle and environmental effects leading to emission of these dust particles, cost incurred from dust effect in agricultural production, health, traffic and finally possible solutions were also suggested to reduce and in essence check dust and enhance a dust free society.

CHAPTER THREE

3.0 METHODOLOGY AND MATERIALS

3.1 Materials

The material to be used in this experiment include

(a) Measuring Tape

(b) Wind Vane

(c) Anemometer

(d) Hygrometer

(e) Thermometer

(f) Standard Sieve

(g) Thick Papers of A1 size

(h) Pins

3.2 Methodology

An unpaved road section of length 100m is chosen for this experiment. On this same road section, the five different vehicles are to run one after the other at three different speeds at a constant time interval. Mark the road section and make a road diversion to improvise for other road users. On this marked road section, fix the thermometer, hydrometer, wind vane and the anemometer at adjacent positions to the road and they should be fixed at 3m away from the road edge.

Place and pin down the A1 size papers 2m away from the road edge where the vehicles are to pass. The papers are to aid in collecting the generated dust particles, while the instrument above are to determine the atmospheric conditions at the experimental site.

Allow five standard vehicles to run across this road section at three different times and at varying speed, assuming the environmental and soil conditions to remain constant.

The variable speeds limit for each vehicle at each run are:

Vehicle	1st speed	2nd speed	3rd speed
Tractor	25km/h	30km/h	35km/h
Nissan truck	25km/h	45km/h	60km/h
Mitsubishi bus	25km/h	60km/h	60km/h
Peugeot 505 car	25km/h	60km/h	80km/h
Toyota Corola Car	25km/h	60km/h	80km/h

The tractor is to run across the road section at 25km/h, and at 30km/h and finally at 35km/h. The dust generated at each speed is to be collected and recorded in accordance with the speed generating it.

This would be repeated using the Nissan truck, Mitsubishi bus, Peugeot 505 car and the Toyota Corolla car respectively. The dust generated should be recorded alongside the vehicle speed producing it.

Also the tape to measure the clearance, tyre contact area of vehicle. Again note the tyre pressure and treading as well as the exhaust pipe position of each vehicle.

At the end of the experiment, all materials, equipment, and vehicles are to be removed. From the road and the road is to be opened for all users.

The dust particles collected are to be analysed by suitable soil / road material test in order to determine size distribution, plastic limit, liquid limit and plastic index of the dust particles collected.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Results

The result of the above experiment/test are given as shown below in Tables I-III and Figure I-V.

Table 1. Vehicle characteristics

Vehicle Type	**Tyre contact are (m2)**	**Tyre treading**	**Tyre pressure (Kg/cm^2)**	**Clearance (m)**	**Vehicle distance from dust collection point (m)**	**Exhaust pipe position**
Tractor (without attachment)	Rear 0.210 Front 0.024	Zig-zag	Rear 17 front 35	0.46	2	Vertically upward
Nissan truck	Rear 0.021 front 0.016	Zig-zag	Rear 50 front 45	0.38	2	Horizontally backward
Mitsubishi bus	Rear 0.019 front 0.015	Zig-zag	Rear 45 front 42	0.33	2	Horizontally backward
Peugeot 505 car	Rear 0.019 front 0.018	Zig-zag	Rear 40 front 36	0.24	2	Horizontally backward
Toyota corolla car	Rear 0.014 front 0.013	Zig-zag	Rear 36 front 34	0.22	2	Horizontally backward

Table II. Records of vehicle speed, amount of dust particles collected at 3-different run/pass at constant vehicle weight.

Vehicle type	Speed (km/h)			Amount of dust (gram)			Weight
	1	2	3	1	2	3	
Tractor	25	30	35	0.82	1.04	1.65	
Nissan Truck	25	45	60	1.88	2.50	3.32	1.723
Mitsubishi Bus	25	45	60	1.90	2.75	3.67	1903
Peugeot 505 car	25	60	80	1.97	301	4.39	1350
Toyota Corolla car	25	60	80	1.92	2.85	4.68	939

Table III. Records of atmosphere/environmental condition at the experimental site.

S/No.	Atmosphere /Environmental condition	Mean Measurement value
1	Temperature	307^0
2	Sun radiation	12.0
3	Moisture/Humidity	53%
4	Wind speed	5.2km/h
5	Wind direction	North East (NE)
6	Latitude/location	9^0N

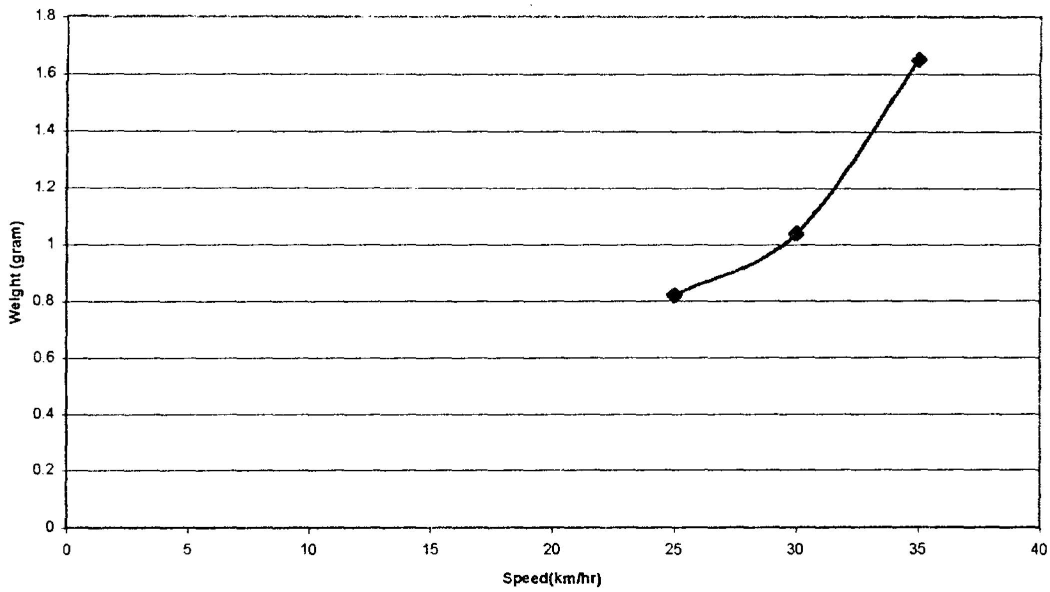

Fig.1 Graph: Amount of Dust Collected Against Tractor Speed

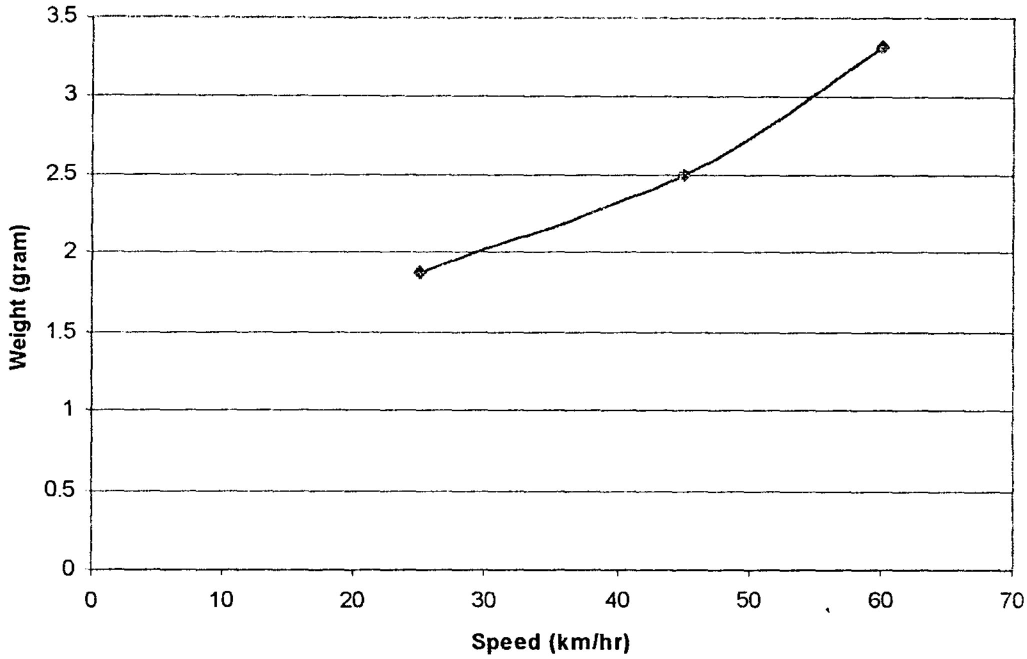

Fig 2 Graph : Weight of Dust Collected Against Nissan Truck

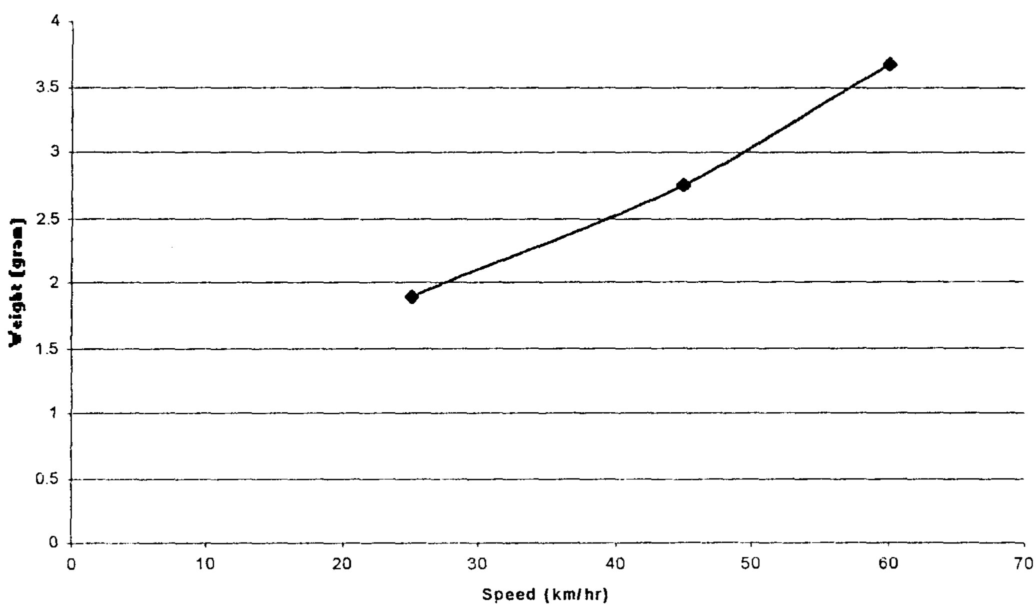

Fig 3 Graph : Weight of Dust Collected Against Mitsubishi Bus Speed

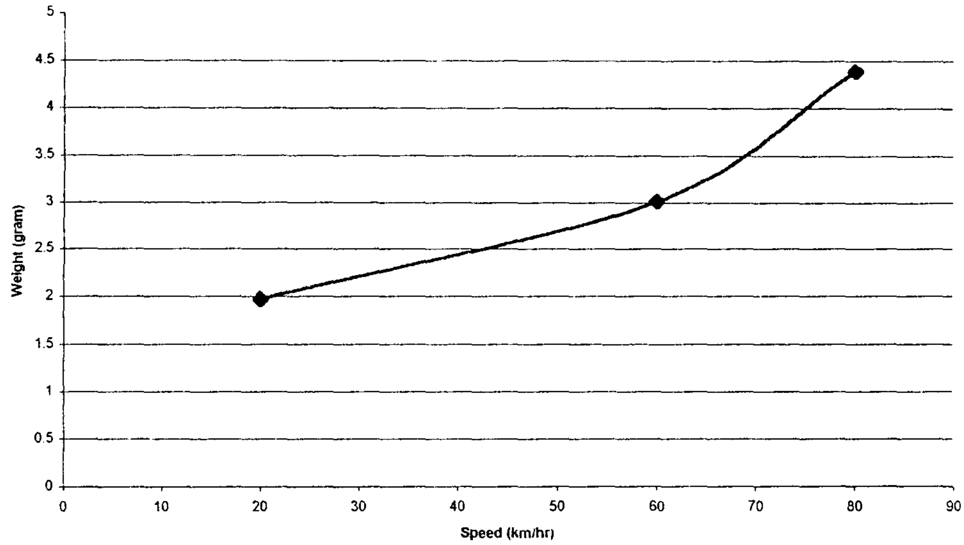

Fig4: Weight of Dust Collected Against Peugeot 505 Speed

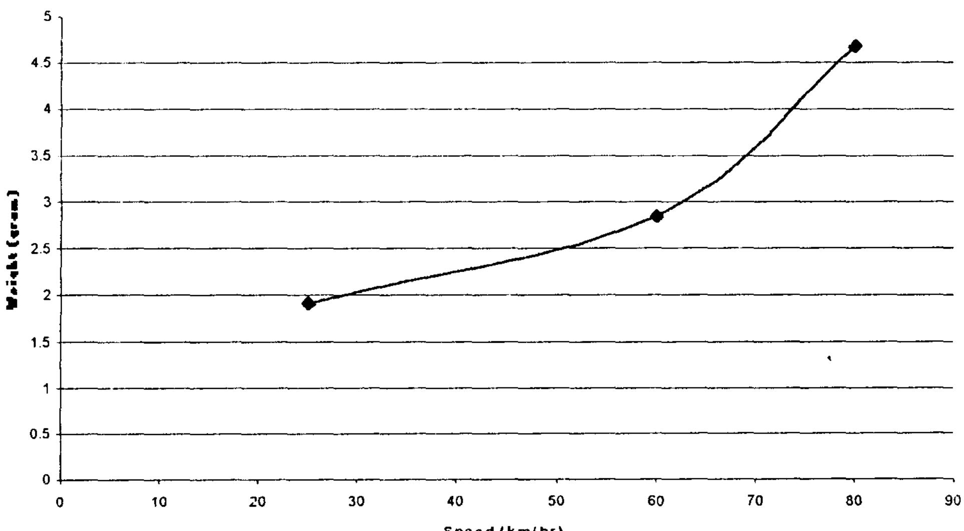

Fig 5 Graph : Weight of Dust Collected Against Toyota Corola Car Speed

4.2 Discussion of Result

The length of the road section was measured to be L=100m.

The width = 3.6m

Hence, from the above, area of the road section considered in this research is calculated to be

$$A = 360m^2$$

Also, the area (A_P) of the paper used in the collection of the dust particles is $A_P = 6177cm^2 = 0.6177m^2$

The number of paper used is 35 and the distance between each paper as was placed along the road section is 1.42m. The length of each of this individual paper is 1.42m as well. This then gives the total distance covered by the papers to be $35 \times 1.42 = 49.7$m.

The average soil lost by these standard vehicles under the stated characteristics and condition was found to be 3.49g in 100m length of road. Therefore, it will be expected that in every kilometer on this road about 34.96g will be lost each day per every passing of five standard vehicles especially at the very dry seasons.

Based on this, if 182 vehicles pass across this road daily, we expect to have a total soil loss of about 6362.72g (182 vehicles x 34.96g) daily.

4.2 Discussion Of Result

The vehicle characteristics in this research are of standard size. The atmospheric/environmental and soil conditions may not be of standard values since they vary from point to point, but those above were used basically in this experiment/test.

The speed range selected is the safest and most appropriate the vehicles can attain normally on this road section. The highest speed could only be attained by light vehicles.

However, it has been established that both vehicle characteristics, soil and atmospheric/environmental conditions give rise to dust emission on unpaved road surfaces. Therefore, since only the vehicle characteristics could be altered during the test, much emphasis are laid on them.

Base on this, it is seen from collected data that the highest dust was collected at the highest speed of the individual vehicle even though other factors were considered.

More so, as the speed varies at each run, the amount of dust particles collected also varies indicating that dust emission is dependent on vehicle speed. But speed alone cannot be the determining and considering factor, hence clearance as well as the weight of the individual vehicle. That is why the tractor with the highest clearance of 0.46m gives only 0.82g of dust at speed of 25km/h.

While Toyota corolla car with least clearance but at the same speed of 25km/h gives off dust of 1.92g.

Interestingly is the situation between the Mitsubishi bus and the Peugeot 505 car which at 60m/h each gives off 3.61g for Mitsubishi and the 505 gives 3.05g. Now, since Peugeot car has lower clearance of 0.24m than Mitsubishi bus with, 0.33m, it should have been expected tat the Peugeot gives off higher dust particles than the Mitsubishi, but this alteration suggests and proof that speed and clearance alone can not be the only responsible factors. Thus, the higher weight of the Mitsubishi has contributed to higher dust emission in this case along side the other factors.

Meanwhile, it should be noted that as the speed increases, the tyre contract area with the unbound road surface decreases leading to reduction of the force disloging the soil particle, whereas dust particles movement will be increasing.

Generally, it can be put that speed is the most important vehicle characteristic considered. This is seen from the graph that at a certain speed, the dust emission rate by each vehicle remain the same. Again, given all other factors, if the vehicles remain in its static and mean position there will be no dust emission. Hence, the vehicle has no relationship with dust emission on unpaved roads if there is no motion/speed.

From the suitable soil material analysis it was found that the sample of dust collected contain mostly sandy clay, sandy clay loam and loam. That is why they are easily disloged and generated as dust.

The fine particle collected ranges between 0.025 – 18mm which give a moisture content of 34.9% on liquid limit test and 16.5% on plastic limit test. From which the plasticity index PI was found to be 28.8% which is not good enough for soil use/on road materials. The best PI for road purpose is given to be between (19-25)% and PI above 25% is not suitable for road purpose.

Hence the reason(s)for the easy emission of dust on the road surface can be linked with the suitable soil test as above.

However, from this road section about 34.9% of soil is expected to be lost given the above conditions daily.

This result to an urgent need for regravelling, stabilizing and possibly paving in order to safe the occurrence of dust emission, surface irregularity, pot-holes and other hazardous effects.

On the whole, no test palliative was carried out, but the ones provided have proofed effective, adequate and appropriate.

4.2.1 Material Lost From The Road

Lost of materials from the unpaved road surface give rise to dust emission. The amount of materials lost from the road depends on the nature and characteristics of both soil, vehicle and the environmental conditions.

However, during the experiment, some sections of the road has great materials lost than others. This is simply as a result of changes and variations in the soil properties.

Meanwhile, the amount of material lost given the above conditions shows that a road section of this kind will highly require yearly regravelling in order to keep a fair road geometry, since some section has to loose greater materials than others. The dislodged materials during the experiment dropped within 5m of the road edge and over 60% fell within $2^1/_2$ m in agreement with Jones (1984) experiment in Kenya and also work by Handy. This however varies as the wind speed but on average, the above is ideal. This wind speed effect on this instance is in agreement with the work done by Leurox and Powers (1960) in quantifying urban dust. The speed of the wind tend to determine the fall/drop position of the lost materials.

Generally, material lost was also dependent on the environmental conditions given other factors to be constant.

4.2.2 Effect Of Vehicle Characteristics

Different vehicles used in this experiment have varying characteristics from each other. These characteristics on their part affect emission and emission rate in a number of different ways. The major ones so considered include the Aerodynamic, total weight of the vehicle, speed and the tyre type and size.

The aerodynamic of the underside of each vehicle type has a significant influence on fine particle emission. Some of the fine material disloged will not be ejected from the road but will be found temporarily in suspension in the vehicle underbody before setting back on the road surface. Hence the higher the clearance, the less particle emission and the vise-versa.

The total weight of the vehicle determines the total pressure or force per unit area acting on the soil/road surface. Base on the soil characteristics, the road surfaces respond differently at each different section of the different weight exerted by the vehicles. Thus, the higher or greater the weight, the greater the pressure and soil breaking force leading to the high emission of fine particles. The reverse is also the case when the weight is very light or low.

The vehicle speed forms and creates the velocity known as the thresh-hold velocity responsible for the initiation of dust movement. The broken fine soil particle are able to reach the collection point as a result of the vehicle speed.

This emission is also dependent on the speed of the vehicle as well as wind speed.

The type and size of the tyre forms contact of the vehicle load with the road surface. The area of contact so created varies with vehicles size of tyre.
The greater the contact area, the greater the particle of soil being broken. Thus, large surface contact area will be expected to give fine emission or otherwise.

The data and corresponding values of the vehicles characteristics and their effects as a result of their interaction on the unpaved road surface will be given in the result section later on.

4.2.3 Effect Of Environmental and Atmospheric Condition.

There is a great evidence of the atmosphere and environmental effects recorded in this research. The evidence suggest a link between the power, mass/amount and velocity of emission of particles on road surfaces given any section of the road subjected to the above effects.
The variation of emission if the fine particles across the sections concerned shows that emission also depends on environmental and atmospheric conditions given the other parameters and effects to be constant.

The conditions so talked about include: Temperature, solar radiation (sunshine),

Moisture content

Wind

Speed and

Direction

Latitude (location) etc.

Temperature has a direct effect on the soil particle by reducing the moisture content of the soil, reducing the soil particle weight and reducing soil binding force holding the soil particle together. Thus high temperature enhances high emission of fine particles on unpaved road surface or otherwise.

Solar radiation has an indirect effect because it only contributes mainly and is solely responsible for the temperature changes: hence within the morning hours, the temperature is low, emission is also low and in the high radiation hours (afternoon) and early hours of the evening, radiation is high, temperature is high as well as emission of fine particles.

Moisture content determines the weight of the soil particle and hence the ease of being emitted from the road surface.

Wind speed contributes to the initiation of movement of the disloged fine particles. The wind effect however determines the distance of travel by the dislodged soil particles within the section of the unpaved road and the road edges.

4.2..4 Dust Movement and Deposition

The dust particles on the surface of the unpaved roads would not have so much adverse effects if they remain in their position at rest on the road surface where they have been disloged.

Consequently, the movement of dust particles disloged from the unpaved road surface is inevitable as long as the vehicle and the atmospheric conditions prevail on such roads.

The disloged soil particles are moved and carried away by both vehicles and atmospheric effects. The movement of the fine particles disloged from the surface form eddy, current around he vehicle wheels and the underbody, this however creates turbulence around the rear of the vehicles which considerably affect the emission and distribution of the exhaust gasses, thus disturbing the free discharge of the exhaust system. This agrees with on tractor's engine emission done by Anders Hanson, Olle Noren and Mats Bohn in 1998.

Dust movement on the road tend to obey the principle of the Brownian, experiment, though rely on the direction of the wind and the vehicles. Base on this, the rate of movement of dislodged soil particles varies within a given point. This is as a result of the particle size and diameter and the characteristics of the toad soil in question. The very lights and small particles travel further and remain in suspension for a longer period than the other heavier and larger particles.

This account for fine collected at various distances within the same experimental condition. But the highest quantity could be collected within a distance of 5meters in all cases. That does nor mean the dust effect have stopped there, but they go as long as distance of travel of the least fine particle emitted, but the intensity of the effect so talked about reduces with the distance of travel.

Generally, dust movement on the road surface takes three distinct processes identified as:

(a) Suspension

(b) Saltation

(c) Surface crop

Suspension is the movement of very fine and light particles in a random form whose distance of travel depends mostly on the win speed, moisture and temperature. They are held for a greater period in the atmosphere before setting on any surface.

Saltation is the movement resulting from the effect of the threshold velocity of both vehicle and atmospheric effect. The particles thus collide with the exhaust emission and are limited in their distance of travel as compared to the former (suspension). As these particles descent to the surface they were found experimentally to travel in straight line with an angle descent of about 6^0 to 12^0.

Surface creep is that which exist a result if the existence of adhesive forces between the vehicle tyre, and the road surface in contact. Some particles of disloged adhere to the tyre and tend to move along and in the same way with the tyre but are dropped off, hence they depend on this force.

On the whole, movement of fine particles is influenced by the particle size, gradation, wind velocity and the vehicle speed. Experimentally, it has been shown that fine particle movement(s) varies as the cube of the excess wind velocity over and above a constant threshold velocity. Again, the particle movement varies directly as the square root of the particles diameter.

Deposition on the other hand occurs when the gravitational force becomes greater than the force holding the fine particles in the air. The however occurs when there is a decrease in the wind velocity as well as the moisture content of the fine particle concern.

4.3 Dust Control on Roads

In order to find an economic solution to the dust problem in the long term, it is necessary therefore to ensure effective measures which will invariably prevent dust emission and check all problems associated with dust on unpaved road surfaces. The control measures suggested and provided in this research have proved adequate and effective if properly applied in controlling dust.

However, these measures vary in their efficiency but the economically suitable ones could be used. The control measures would not only control dust emission but also reshape the existing road surface., improve and increase soil binding forces, compact and shape the road surfaces into a completed road way.

As a rule, all dust control measures should be carried out only as stated specifications with regard to soil material and characteristics of the road section. Otherwise they may be wrongly applied and a good aim and project destroyed. And in addition, adverse effects may be delivered to soil materials, environment and even the vehicle leading to more devastating effects likely to be more detrimental than the dust problem.

4.3.1 Stabilized Road Surface

The term "stabilized road" has long denoted a class of surfacing built by combining soil material or by adding calcium or sodium chloride or certain organic compounds to the material or its surface. Not included in this classification are asphalt, stabilized layers where the surface is protected by a seal coat. Proper and adequate addition of soil stabilizers increase soil resistance to destructive weather conditions by binding the dust material together on the road surface, reducing soil shrinkage and swelling, making the soil to be water proof and less permeable to moisture.

To control dust, the primary aim is to stabilize the road surface, road stabilizing has the advantages of controlling dust, increasing vehicle efficiency high productivity, low accident rate etc.

The different stabilizing materials or compounds suggested to control dust on this unpaved road surfaces include:

Geotextile (Fabrics) application: application of bitumen seals; coating with deliquescent salts; application of waste sulphur liquo application of oiled gravel; admixture of various local materials such a molasses, bamboo, palm oil, animal fats, lime, charcoal etc. application of water and application of pennzsuppres®D.

Pennzsuppres ® D. is proved to be more efficient and economical in controlling dust on remedial bases.

Below is the table showing the soil stabilizing materials use in road dust control.

Typical application and uses of dust fabrics.

Application	Use
Drain filter	Trench, drains, base course etc
Subgrade stabilization Light Heavy	Parking lot pavement, Airport pavement Haul road, storage yards, rail roads.
Reinforcement Light Heavy	Low fill foundation, low retaining walls. High embarkment, high retaining walls
Erosion control Light Medium Heavy	Ditch armour, culvert oulet protection Small to medium wave protection Large wave protection
Site fence	Construction site
Reflection crack control	Asphalt overlays Asphalt pavement over cement stabilized bases canal lining repair
Drainage	Foundation consolidation Embarkment consolidation

For better result a combination of the stabilizers may be required, though one would probably predominate.

Trade name	Description
Aerospray	Polyvinyl acetate diluted 1 to 20 of water
Surfaseal	Trade name diluted 1 to 20 of water
Petroset	Bustiadene styrene subber and resin in oil emulsion diluted 1 to 20 of water
Coherax	Petroleum resin diluted 1 to 14 of water
Dresinate DS—60W80F	Thermoplastic resin diluted 1 to 9 of water
Paracol 1461	Wax thermoplastic resin dieted 1 to 9 of water
Terakrete	Vinyl acetate copolymer diluted 1 to 16 of water
Dust control oil	Petroleum resin
Dust stop	Acrylonite butiadene styrene copolymer diluted 1 to20 of water
Faramine 99-194	Urea formaldehydene resin diluted by 40% water
Norlig 41 + F 125	Combination of ligain sulphonate and sodium methyl diluted 1:4 and 1:40 to water respectively
Curaol A.E	Polymer dispersion, diluted 1 to 6 of water
Dust Bond 100	Liquid sulphonate and sodium methylated
Redicote E-52	Cationic asphalt emulsion

4.3.2 Machines To Improved Unpaved Roads

The unpaved road surfaces that generate dusts are often made of soil materials with poor engineering properties unable to withstand the load and other characteristics of the vehicle and the atmosphere. Thus, the road surface is very irregular and poor in geometry, has loose soil material (dust and slippery especially in wet seasons.

To check/control dust effectively, certain machines are use to work upon the road surfaces which help in improving the soil engineering properties with abilities to redistribute the applied vehicle load, reduce stress transmission in the soil and to be used effectively as roads that generate a minimum amount of fine particles.

These machines generally include;

(a) The CAT D_8 Dozer

(b) CAT 612 scraper

(c) CAT 130G Grader

(d) CAT 950 Loader

These machines, if properly, appropriately and adequately used to work on the unpaved road surface dust emission will be controlled to a good extent.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

Specially, dust has been defined as a finely powdered and minute earth particle of mineral and or plant material lying on any material on the earth surface and some suspended in the atmosphere. The dust so talked about has about 77% of soil as the highest constituent.

While unpaved road is a road that is made of natural earth material and whose foundation and wearing surface are composed of natural soil materials.

Due to vehicle interaction on these roads, dust is generated and the dust is partly suspended in the atmosphere, also some settled on any matter on the earth surface.

This dust in the atmosphere and earth surface is increasing with increase use of vehicles. The effect of dust are on alarming stage on global warning. Generally, dust is emitted from other sources including desert storm, mining activities, building and farming activities and vehicle interaction on unpaved roads. And of these, vehicle interaction on unpaved road has been found to be a source generating more dust than others worldwide. The dangerous effects of dust from unpaved road surfaces include the following: Environmental pollution, increase cost of agicultural production, increase cost of vehicle maintenance, increase health problem (chest pains, cough, nasal and eye irritation), poor visibility irregular road geometry and accident, all of which lead to death.

Therefore, in order to find out why and how dust is generated and a the effect therein, a research was conducted and a field work carried out to investigate cause(s), quantify the amount and find control measures to dust on both road surfaces, homes and the environment at large.

However, understanding the potential of both vehicles and the unpaved road surfaces to emit dust can help improve vehicle efficiency, reduce maintenance cost, safe guard the environment as well as protect life generally for man, animal and plants and increase national standard of living. That is why a section of the unpaved road was choosenas an experimental site and the experiment conducted in the dry season to ensure highest dust emission (good result).

It must be noted that dust is emitted by all vehicles,--both new and old, big and small but the amount emitted by each varies and depend on the vehicle characteristics such as weight, speed, aerodynamics, maintenance standard and age and modifications etc. Dust emission also varies along the sections of the road as a result of the soil engineering properties of the given road section as well as the atmospheric conditions.

Dust as a whole is related to how much silt is in the road material. Dislodging of soil material also depends on the soil engineering properties while dust movement and distance of travel is related to the individual particle diameter and weight.

5.1 Conclusion

The aims and objectives of the project were successfully achieved. Sources, amount and possible solutions of dust particle emission on unpaved road surfaces were achieved. However, not all the criteria were met in an excellent way in this research but the available ones are ideal and satisfactory, informative and useful.

Very fine particles of dust that settled on the surface of plants prevent adequate and appropriate reception of sun light by plants, this disturbs the photosynthetic effect leading to poor growth and yield. Again for respiratory purposes, inhaling above the permissible range of 0-0.09g of dust particles will cause health hazards whereas over 0.83g – 4.68g of dust was generated on this 100m road section by the five vehicles after 3 passes by each. And on average 3.49g of dust particle is lost per vehicle after 3 passes on this road section, thus, 684.04g of road material is expected to be lost yearly leaving the road surface very irregular, susceptible to erosion, and disturbing vehicle maneuverability. Hence, the high need for yearly regravelling and stabilizing of the unpaved surfaces.

The major factors responsible for dust on unpaved roads are vehicle characteristic, road material (soil type), environmental and atmosphere conditions. However, until now, the new Pennsuppress®D remains the best remedial treatment of dust on unpaved road.

Finally, for a long-term operation and advantage, all unpaved roads should be made paved.

5.2 Recommendations

It should be a realistic and acceptable fact to all that dust is real and its effects are hazardous to men, plant, animal, buildings, machines, equipment and vehicles.

Vehicle owners/user should be mindful of modifications, which can contribute to dust emission on unpaved roads.

A body such as the National Ambient air Quality Standard (NAAQS) should be set up alongside the Federal Environmental Protection Agency (FEPA) and other health bodies in order to improved the environmental air and set rules to guide the levels of extremely small fine air born particulate (dust) as it is done in developed nations.

Dust though is seen as a menace should not be completely eradicated but be controlled and the amount minimized since it is essential in the occurrences of some natural phenomenon such as the twilight and the red colours displayed by the sun at it rising and setting, and also it served as nuclei around which water vapour condense to form cloud, giving rise to rain and the hydrological cycle.

At this juncture then, it is strongly recommended that the government should give attention to feeder, rural and farm roads, to improve and pave them. Where this is not done, refilling and grading should be carried out regularly. Water, charcoal, waste sulphur, oils and other locally available road stabilizing materials should be used on unpaved road surfaces.

Finally, even for political reasons, government and other benevolent organizations should enhance programmes that will bring about development and high living standard of over 70% of Nigeria population who are found to be rural dwellers and farmers through stabilizing and paving the roads.

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