

# ROAD DUST - JUST A NUISANCE OR A SIGNIFICANT ROAD MANAGEMENT ISSUE?

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## INTRODUCTION

There are estimated to be over 500 000 km of unsealed roads in South Africa, which are managed by the provincial road authorities (~ 150 000 km), local authorities (~ 200 000 km, including those unproclaimed roads in developing communities), the forestry industry (~ 100 000 km), agriculture (~ 50 000 km), the mining industry (~ 5 000 km) and nature conservation and tourism (~ 5 000 km). Service roads belonging to Spoornet, Eskom and Telkom are not included in this total. Unacceptable levels of dust are experienced on many of these roads.

In the past, road dust has only been considered as a nuisance factor. However, there is a growing awareness that the dust generated by vehicles on unsealed roads has significant environmental and social impacts in terms of health, safety and visual pollution and substantial economic impacts pertaining to the loss of road construction material, higher vehicle operating costs, reduced agricultural yields and increased building maintenance.

In this paper, the consequences of road dust are quantified and various techniques and their cost-effectiveness as apart of an unsealed road maintenance strategy, are described.

## CONSEQUENCES OF DUST

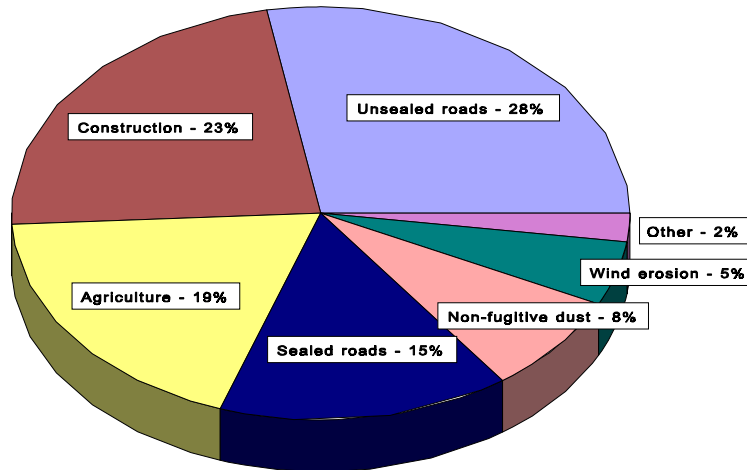
There are numerous consequences associated with dust which is generated by traffic (and to a lesser extent, wind) travelling on unsealed roads. Many of the impacts are overlooked or disregarded by road authorities and road owners. However, road users, workers on mines, forests and other such environments, as well as people living adjacent to unsealed roads are becoming increasingly demanding for improved driving, working and living conditions. In the future, road authorities will have to consider these impacts during the development of maintenance strategies and the implementation of maintenance plans.

### Volume of Dust Generated

The consequences of road dust cannot be fully appreciated without a reliable estimate of the quantity of dust that is generated annually. Unfortunately, road dust is not measured at national, provincial or local level in South Africa and therefore no domestic figures are available for this discussion. Apart from the need for information to address the concerns relating to road dust, there is growing pressure from a number of sources for the setting and monitoring of comprehensive ambient air quality standards in the country to reduce the growing trend of increased neonatal deaths and increased respiratory illness and mortality associated with air pollution.

In the United States, particulate matter (PM<sub>10</sub>) (in which dust from unsealed roads is categorised) has been comprehensively monitored, along with numerous other emission categories, since the early 1970's. These figures are readily accessible and have been used to provide a background for this study. The 1995 US National Particulate Matter (PM<sub>10</sub>) emissions are illustrated by principle source category in Figure 1<sup>1</sup>. Of the 43 million tonnes of PM<sub>10</sub> generated, approximately 12 million tonnes was attributed to dust from unsealed roads. A breakdown of South African emissions is probably similar to

that of the United States, although that attributed to construction is probably lower, given the current minimal activity in this arena. The dust attributed to unsealed roads, agriculture and wind erosion will be higher given the long dry season, relatively high temperatures and net evaporation loss experienced in South Africa.



**FIGURE 1: US PM<sub>10</sub> emissions by principal source category<sup>1</sup>**

Conservative estimates of the dust generated on South African unsealed roads have been made using the United States Environmental Protection Agency (EPA) AP-42<sup>2</sup> dust prediction model (Equation 1).

$$E = k \left( \frac{s}{12} \right) \left( \frac{S}{48} \right) \left( \frac{W}{2.7} \right)^{0.7} \left( \frac{w}{4} \right)^{0.5} \left( \frac{365 - p}{365} \right) \dots \dots \dots \text{Equation 1}$$

- where E = emission factor in kg/vehicle km
- k = particle size multiplier
- s = silt content (<0.075 mm) of surface material (%)
- S = average vehicle speed (km/h)
- W = average vehicle weight (tonnes)
- w = average number of wheels
- p = mean annual days with rainfall greater than 0.25 mm

For South Africa the equation reads as follows (Equation 2):

$$E = 0.8 \left( \frac{15}{12} \right) \left( \frac{60}{48} \right) \left( \frac{1.5}{2.7} \right)^{0.7} \left( \frac{4}{4} \right)^{0.5} \left( \frac{365 - 130}{365} \right) \dots \dots \dots \text{Equation 2}$$

= 0.534 kg/vehicle km

The dust (D) generated per annum (assuming traffic volumes in Table 1) is therefore:

vehicle km/annum	=	1.55 x 10 <sup>7</sup> x 365
	=	5.657 x 10 <sup>9</sup>
D	=	5.657 x 10 <sup>9</sup> x 0.534
	=	3.019 x 10 <sup>9</sup> kg
	=	3.0 x 10 <sup>6</sup> tonnes

The approximate three million tonnes of dust generated equates to 0.19 tonnes of dust generated per annum for every vehicle travelling one kilometre of unsealed roadway once a day, every day of the year. The figure calculated by the United States Forest Service for unsealed roads in America was 0.6 tonnes<sup>3</sup>.

**TABLE 1: Traffic volume assumptions for SA unsealed roads**

AUTHORITY	DISTANCE (km)	AVERAGE VPD <sup>1</sup>	km/DAY (x 1 million)
Provincial	150 000	50	7.5
Local	200 000	30	6.0
Forestry	100 000	6	0.6
Agriculture	50 000	2	0.2
Mining	5 000	6	0.6
Tourism	5 000	6	0.6
Total (million km/day)			15.5

<sup>1</sup> vpd = vehicles per day

Note

No comprehensive traffic data for unsealed roads are available in South Africa. The above figures were derived from the personal experience of the author and other practitioners and tested against South African fuel usage figures as follows:

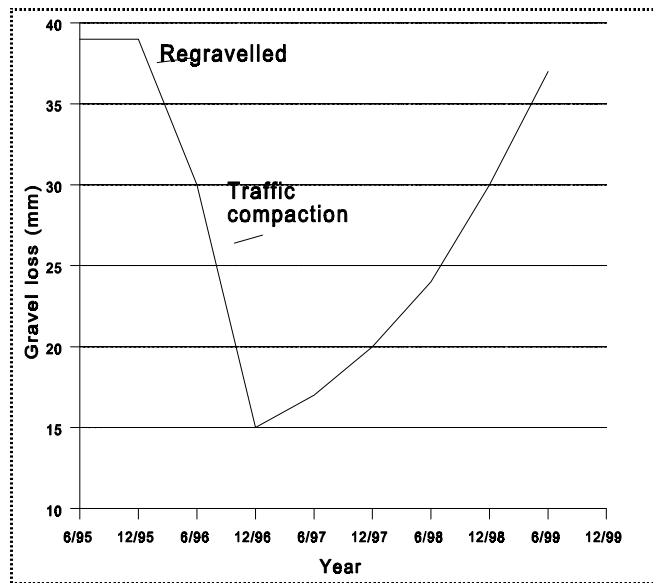
Total SA fuel usage (diesel and petrol) <sup>4</sup>	=	1.70 x 10 <sup>10</sup> F/annum
Assume 5% of traffic uses unsealed roads	=	8.5 x 10 <sup>8</sup> F/annum
	=	2.33 x 10 <sup>6</sup> F/day
Assume average consumption of 7 km/F	=	16 300 000 km/day

For the purposes of this study, 15 500 000 km/day is considered a conservative, but acceptable estimate for the traffic on South African unsealed roads.

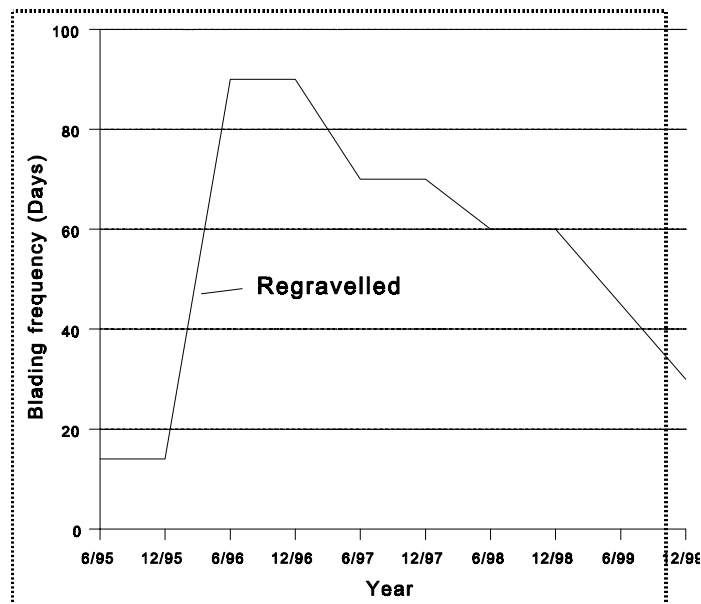
**Gravel Loss**

Of the approximately three million tonnes of dust generated on unsealed roads discussed above, about two-thirds, or two million tonnes will probably settle back onto the road to be entrained by the next vehicle. Depending on climatic conditions (wind and temperature) at least one-third of the material, or one million tonnes will be lost from the road. It is these soil fines that bind larger particles together to form the road matrix. Once lost, the consequent increase in the rate of loss of coarser particles as a result of ravelling of the material under traffic over time will be apparent. Other problems associated with the loss of soil fines including potholing and corrugations will result and will become more severe with time, thus contributing to increased road roughness. This in turn leads to the need for more frequent maintenance. A loose gravel surface deficient in binder also increases the incidence of broken windscreens, headlights and damage to bodywork.

The effect of the loss of fines on the rate of gravel loss and deterioration in riding quality has been monitored as part of a number experiments<sup>5,6</sup>. On particularly dusty roads, it was noted that, over time, the rate of gravel loss increased each year. The frequency of blading also increased. Although traffic volumes also increased during the period, it is believed that the loss of fines in the form of dust contributed to the increasing rate of deterioration. Graphs illustrating the increased rate of gravel loss and required maintenance on an unsealed road are presented in Figures 2 and 3 respectively.



**FIGURE 2: Plot of gravel loss over time**



**FIGURE 3: Plot of blading frequency over time**

### Safety Hazard

On dusty unsealed roads, the safety hazard increases for motorists, cyclists, pedestrians and live-stock as a result of reduced visibility for following and approaching vehicles. It should also be remembered that streets in developing communities are often the only social gathering points for residents, that children play on them and various sporting activities are conducted on them. Dust is a significant hazard under these conditions.

In 1996 and 1997 (latest figures available), collisions on unsealed roads in a dry condition (ie dusty) accounted for 4.2 per cent (21 908) and 3.7 per cent (18 897) respectively of all collisions reported in South Africa (520 774 and 505 988)<sup>7,8</sup>. Of the number of fatal collisions reported, 5 per cent and 10 per cent occurred on urban and rural dry unsealed roads respectively in both years. Of the number of major collisions (no fatalities) reported, the figures were 5 per cent and 13 per cent respectively in both years. Although there is no formal mechanism for reporting whether dust was a factor in the cause of the collision, it can be assumed that it did contribute in many instances. Dust therefore has a

considerable impact on the safety of road users given that only about five per cent of traffic travels on unsealed roads. The relevant 1996 and 1997 statistics are summarised in Tables 2<sup>7</sup> and 3<sup>8</sup>.

### Vehicle Operating Costs

Most vehicle manufactures recommend doubling the maintenance frequency when a vehicle is operated predominantly on unsealed roads. Unfortunately, no accurate records of vehicle operating costs specifically associated with dust are available in South Africa. However, discussions with a number of fleet operators confirmed that life expectancy of filters, lubricants and exposed moving parts (eg universal joints) was significantly shorter in comparison with the same vehicles operated on sealed surfaces<sup>9</sup>.

### Other Impacts

Health: It is well documented that numerous respiratory diseases are attributed to high levels of fugitive dust. The prolonged inhalation of road dust can result in respiratory ailments and the aggravation of existing health problems, especially if the dust particles are combined with contaminants. In South Africa, dust from unsealed roads in developing communities contributes to as much as 16 per cent of the airborne particulate matter in those areas<sup>10</sup>. The same study linked the high incidence of respiratory disease, especially amongst children, to the higher ambient air pollution levels.

Discomfort and Nuisance: Discomfort for pedestrians, vehicle occupants and residents of properties adjacent to the road is significant on dusty unsealed roads. Of particular concern is the accumulation of dust inside dwellings and the soiling of curtains and washing.

Agricultural Yields: Reduced agricultural yields and palatability of vegetation for livestock and wildlife can also be attributed to road dust. Dust coatings on crop foliage reduces the efficacy of the transpiration and photosynthesis processes, reduces spray contact of pesticides, fungicides and fertilisers and causes leaf and fruit scorch which, together with adhered dirt and discolouration, reduces the selling price of the product. Dust also reduces the activity of parasitic insects which prey on pest insects.

In a study<sup>11</sup> commissioned by the former Cape Provincial Administration, research using infra red aerial photography indicated that trees in fruit orchards adjacent to unsealed roads were smaller and less productive than trees more distant from the roads. In the first three rows closest to the road, between 80 and 100 per cent of the trees were smaller than the average for the orchard. Tree size and leaf coverage improved with distance from the road until no apparent effect was noted in the eighth row. The study also found that one or two additional insecticide spray applications were required on trees adjacent to the road to control the increased insect activity and to counter the influence that dust has on the parasitic insects. Chemical costs alone increased by between R1 500 and R2 200/km (1992 costs). The potential financial loss in terms of income was more dramatic and is summarised in Table 4<sup>11</sup>.

**TABLE 4: Potential financial losses in the fruit industry<sup>11</sup>**

DAMAGED FRUIT		LOSS IN FOREIGN EARNINGS (1992 R)	LOSS FOR THE PRODUCER (1992 R)
% Damage	Tonnes Rejected		
0.5	2 687	4 455 046	1 514 715
1	5 374	8 910 092	3 029 431
2	10 748	17 820 184	6 058 862
3	16 121	26 728 618	9 087 730
4	21 496	35 640 368	12 117 725
5	26 869	44 548 802	15 146 592

No studies have been conducted in South Africa on the impact of road dust on other crops or roadside pasture<sup>12</sup>. However, studies in New Zealand<sup>13</sup> indicate that dust from unsealed roads contributes to a one per cent decrease in lambing rate and reduced milkfat yields related to both depressed pasture yield and a reluctance of livestock to eat contaminated pasture. Dust settling on pasture areas may also cause premature wear of the teeth of grazing animals.

## **DUST CONTROL**

### **Introduction**

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<sup>14</sup>. 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.

Research on dust palliatives has been conducted over a period of more than six years on behalf of road authorities and product manufacturers. In order to facilitate the selection of an appropriate product for particular conditions, South African dust palliatives have been divided into the following ten categories:

- \$ water and wetting agents;
- \$ waste oils;
- \$ hygroscopic materials;
- \$ ligno-sulphonates;
- \$ modified waxes;
- \$ petroleum resins;
- \$ synthetic polymer emulsions;
- \$ tars and bitumens;
- \$ sulphonated oils,
- \$ other products.

Water and wetting agents are only suitable for very short term applications. Waste oils may not be used in South Africa as the potential for groundwater pollution is too high. Other products are those such as tannin extracts, molasses and plant extracts, and industrial wastes. These products are often only available in small quantities, regionally specific and may have environmental implications in terms of leachate.

For the other seven categories, research has been directed towards the development of material, climatic, construction and application, maintenance and rejuvenation guidelines and performance prediction models. Product performance is also considered in terms of basic requirements, which include availability in sufficient quantities at realistic prices, adequate durability and resistance to deterioration by evaporation, ultra-violet light and chemical reactions, ability to penetrate compacted materials and ability to withstand leaching by water. In addition, products should be non-flammable after application and should not cause corrosion to construction equipment or to vehicles using the road after application. The product residue should not adhere to tyres or shoes and any product used should be environmentally acceptable, with potential leaching constituents having no negative impact on ground water, or being toxic to humans, animals or plants.

## **Hygroscopic Salts**

These products, which include calcium chloride, sodium chloride and magnesium chloride, absorb moisture from the atmosphere and bind the material particles together, thus preventing them becoming entrained by vehicles. Detailed research on the use of calcium chloride on unsealed roads in southern Africa has been conducted and more than 30 experiments, selected according to a comprehensive experimental design, on provincial, municipal, forest, mine and farm roads have been monitored. Results indicate that the product can be used as a cost-effective dust palliative and as an interim means of providing an improved driving surface until such time as the road can be upgraded to a sealed surface. Material, climate, construction and maintenance specifications for applying calcium chloride in southern Africa have been defined and performance prediction models have been developed to allow a performance guarantee to be negotiated between the supplier and the road authority<sup>15</sup>. The prediction models have also been incorporated into the Gauteng Department of Transport and Public Works unsealed road management system. Calcium chloride is now widely used in South Africa where it is applied as a spray-on application.

In terms of cost-effectiveness, the rate of gravel loss and riding quality deterioration of calcium chloride treated sections was compared with untreated sections on the same road. Over a period of 12 months, typical gravel loss on the treated sections was about 5 mm, compared to between 25 and 55 mm on the untreated sections. Blading frequency on the treated sections averaged 150 days compared to 40 days on the untreated sections. Cost-benefit analyses over a 10 year period using a discount rate of 12 per cent indicated a break-even traffic volume of about 70 vehicles per day and a nett present value of about R310 000/km (1996 terms) accruing to the road authority (savings in maintenance) and the road user (savings in vehicle operating costs) for traffic volumes of 400 vehicles per day (actual for the road).

## **Ligno-sulphonates**

Ligno-sulphonates are by-products from the sulphite pulping process commonly used in the pulp and paper industries. Their composition is variable and depends on the timber and chemicals used to extract the cellulose. When used as dust palliatives, they bond the particles of the road together, thus preventing them becoming entrained by vehicles. Research on ligno-sulphonates is presently being undertaken and experiments are being monitored on provincial, forest and mine roads. Initial results indicate that the product can provide both cost-effective dust control and an improved driving surface until the road is upgraded to a sealed surface. Interim material, climate, construction and maintenance specifications for applying ligno sulphonate in southern Africa have been defined. In its present form, the product is soluble and tends to leach from the road during heavy rainfall, thus requiring intermittent rejuvenation. The product is therefore more effective in dry areas than in wet areas<sup>16</sup>. Ligno sulphonates are increasingly being used in South Africa where they are applied using either a mix-in or a spray-on process.

## **Modified Waxes**

Modified waxes are manufactured as part of the oil from coal process in South Africa. When applied to unsealed roads in the vicinity of the plant, they have exhibited soil binding properties. Interim laboratory and field studies on the use of modified wax have shown that the product has potential for use as a short-term dust palliative on unsealed roads in southern Africa. Basic guidelines on the use of the product have been prepared. Modified waxes are currently only being applied for experimental purposes in South Africa, mostly as a spray-on application<sup>17</sup>.

## **Synthetic Polymer Emulsions**

Synthetic polymer emulsions, or more correctly, polymer dispersions, are suspensions of synthetic polymers in which the monomers are polymerised in a dominantly aqueous medium. Numerous formulations have been developed for various soil Aconditioning® applications, many of which are suitable for dust control and gravel preservation on unsealed roads. A number of products are currently available. Most of the documented research on polymers has been conducted in the

agricultural industry where the products have been used to bind soils to prevent erosion by wind and water. Only limited documented research has been conducted on the application of the products to roads. Interim laboratory and field studies on the use of synthetic polymer emulsions, much of which has been carried out by the product suppliers, has shown that the product has potential for use as a dust palliative and stabiliser on unsealed roads and even as a stabiliser for base and subbase construction for sealed roads, although certain products are still susceptible to weakening when wet. Further research should be carried out to determine whether the various products can be used cost-effectively in southern Africa. Certain products have been used on sandy materials in KwaZulu-Natal with reported success, but most are still currently being used for experimental purposes, using a mix-in process. Initial experiments using a spray-on application proved unsuccessful due to poor penetration. No published guidelines have been prepared.

### **Petroleum Resins**

Petroleum resins are imported into southern Africa from the United States. Although research had been conducted in the United States on product performance on public roads, studies in South Africa was required by the road authorities prior to it being used locally. Interim laboratory and field studies have shown that the imported product is an effective dust palliative and stabiliser. However, importation costs are high and ongoing research will determine whether the product can be used cost-effectively. Local guidelines will be prepared if the product proves viable. The product is currently being used for experimental purposes in quarrying operations, as a spray-on and mix-in process<sup>17</sup>.

### **Tars and Bitumens**

Tar and bituminous products are offered by most petrochemical and bitumen suppliers as part of their product line. Tar-based products are derived from coal tar distillates to which solvents are added to improve penetration. Bituminous products are generally 80/100 Penetration Grade bitumens to which solvents are also usually added. Products range in price and durability from simple spray-on applications that will last approximately four weeks before requiring rejuvenation, to thicker applications that can be blinded with sand, which perform similarly to sand seals and which can last up to three years before requiring rejuvenation. Although fairly widely used, only limited documented research has been conducted on the application of these products to unsealed roads<sup>17</sup>.

The performance of these products is very dependent on the quality of the base material and on the drainage. Weak materials will deform under traffic, causing rutting and potholing which have to be repaired manually. Cracking of the surface over time allows the ingress of water which leads to rapid deformation of the road which cannot be maintained with a grader. If the base materials are of adequate strength and if the pavement can be kept dry at all times, the products can provide an all weather surface as a short term measure until the road can be upgraded.

### **Sulphonated Oils**

These products, which consist primarily of strongly acidic sulphur-based organic mineral oils, were developed in the United States in the early 1960's and have since been marketed all around the world. No comprehensive scientific research programme appears to have been conducted on the performance of these chemicals and this, together with the secrecy around the composition of the products, has resulted in them having little significance in the road building industry by comparison with other chemical stabilisers such as lime, cement and regular bituminous products. In South Africa, sulphonated oils are not marketed as dust palliatives but rather as soil modifiers. However, in certain circumstances, probably as a result of improved compaction, they may also reduce dust levels after construction.

### **Product Selection**

The choice of product for dust control depends on the material characteristics, climate, traffic, road geometry, available equipment and the needs of the client. Most products have been developed to



perform best under particular circumstances, with no single product providing an all encompassing solution to dust control on unsealed roads.

An interim guideline product selection matrix, based on the limited experience of the author and using various typical selection parameters is provided in Table 4.

**TABLE 4: Interim product selection matrix**

<b>PARAMETERS</b> <b>PRODUCT</b>	High Pl m a t e r i a l s ( > 10 )	Med i u m Pl m a t e r i a l s	S a n d y m a t e r i a l s	All w e a t h e r p a s s a b i l i t y	St e e p g r a d i e n t s	H e a v y v e h i c l e s	H i g h t r a f f i c v o l u m e s	S h o r t t e r m a p p l i c a t i o n s	L o n g t e r m a p p l i c a t i o n s *	S p r a y 	M i x - i n a p p l i c a t i o n	G r a d e r m a i n t e n a n c e
Wetting agents		H			H			H		H		H
Hygroscopic salts		H				H	H	H		H	H	H
Ligno sulphonates	H	H	H			H		H			H	H
Modified waxes		H						H		H		H
Synthetic polymer emulsions	H	H	H	H	H	H			H		H	
Petroleum resins	H	H		H	H	H		H		H	H	
Tars and bitumens		H		H					H	H		
Refined bitumen emulsions**	H	H	H	H	H	H		H	H	H	H	H
Sulphonated oils	H			H	H	H	H		H		H	H
<p>* Other products can be applied as long term applications, but will require periodic rejuvenation</p> <p>** Refined bitumen emulsions are marketed by the suppliers as part of a road maintenance strategy for mine, forest and farm roads. The product and strategy are modified to suit the requirements of the particular situation.</p>												

This matrix does not pretend to be exhaustive and should be used as a general guide and introduction to dust control only, with the particular circumstances of each application being thoroughly considered and investigated before choice of product is made. Individual products in the various categories may also be modified by the manufacturer to suit the particular conditions of an application and to overcome one or more of the general limitations of that category. The matrix also assumes that mechanical modification of the material is not carried out prior to application. Changes to the product and/or improvement of the material prior to application would obviously alter the parameters used in the selection matrix. Product performance under the conditions of the particular road should be discussed with the product suppliers before a decision on the choice of product is made.

## DUST CONTROL PROGRAMMES

Although numerous acts and ordinances are applicable to the roads and transport industry and a number of these provide measures to exercise control over the negative environmental impacts of road transportation, either directly or indirectly, there is no legislation in force in southern Africa, apart from that regulating the mining industry, which relates directly to dust from unsealed roads. Dust control is therefore generally considered in terms of economic benefits rather than in terms of environmental benefits, although in recent years, dust has often been identified by interested and affected parties as a potential impact requiring assessment and possible mitigation in new development projects.

Given the information in previous sections, it is imperative that the economic impacts of dust in terms of unsealed road deterioration and increased vehicle operating costs are determined and controlled as part of a road management system. Appropriate decision support processes for optimising funding for road maintenance and dust control activities have been developed to suit the particular needs of individual road authorities. The performance prediction models that have or are in the process of being developed can be incorporated into these systems to enhance the optimisation process. Systems will obviously vary depending on the type of network and the characteristics and locality of a particular road and the traffic using that road.

## CONCLUSION

It is firmly believed that road dust is more than a nuisance and is in fact a significant road management issue. Studies have shown that more than 3 million tonnes of dust are generated on South African unsealed roads each year, of which at least 1 million tonnes are lost to adjacent areas. The impacts of this are seen in increased rates of gravel loss and the need for more frequent road maintenance. The safety of all road users is also affected, while vehicle operating costs increase. Although not fully quantified, the impacts on human health and agricultural yields are also significant.

Research has shown that better material selection, mechanical stabilisation or the application of a chemical dust palliative are all cost-effective measures for reducing road dust. Appropriate material selection guidelines are readily available in South Africa. Comprehensive research has also been carried out on a number of dust palliatives and performance prediction models are available for inclusion in gravel road management systems.

## ACKNOWLEDGEMENTS

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**TABLE 2: Collisions according to surface and condition of road - 1996<sup>7</sup>**

SURFACE	TOTAL			FATAL		MAJOR		MINOR		NO INJURY	
	Total	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Sealed - dry	431 295	394 406	36 889	3 970	2 543	15 790	3 201	38 231	6 128	336 415	25 017
Sealed -wet	63 521	56 501	7 020	399	344	1 635	459	5 275	1 160	49 192	5 057
Unsealed - dry	<u>21 908</u>	<u>15 234</u>	<u>6 674</u>	<u>235</u>	<u>309</u>	<u>928</u>	<u>552</u>	<u>1 633</u>	<u>1 340</u>	<u>12 438</u>	<u>4 473</u>
Unsealed - wet	4 050	2 949	1 101	20	30	90	52	250	173	2 589	846
Total	520 774	469 090	51 684	4 624	3 226	18 443	4 264	45 389	8 801	400 634	35 393
% Unsealed - dry	4.2	3.2	12.9	5.1	9.6	5.0	12.9	3.6	15.2	3.1	12.6

**TABLE 3: Collisions according to surface and condition of road - 1997<sup>8</sup>**

SURFACE	TOTAL			FATAL		MAJOR		MINOR		NO INJURY	
	Total	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Sealed - dry	422 551	386 825	35 726	4 111	2 519	16 533	3 070	41 233	6 406	324 948	23 731
Sealed -wet	60 873	54 418	6 455	381	236	1 542	427	5 362	1 094	47 133	4 698
Unsealed - dry	<u>18 897</u>	<u>13 135</u>	<u>5 762</u>	<u>227</u>	<u>264</u>	<u>854</u>	<u>491</u>	<u>1 665</u>	<u>1 228</u>	<u>10 389</u>	<u>3 779</u>
Unsealed - wet	3 667	2 670	997	26	26	87	55	250	153	2 307	763
Total	505 988	457 058	48 940	4 745	3 045	19 016	4 043	48 510	8 881	384 777	32 971
% Unsealed - dry	3.7	2.9	11.8	4.9	8.7	4.5	12.1	3.4	13.8	2.7	11.5

## ROAD DUST - JUST A NUISANCE OR A SIGNIFICANT ROAD MANAGEMENT ISSUE?

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