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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590
REPLY TO THE ATTENTION OF

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Dust Suppression on Wyoming's Coal Mine Haul Roads

Literature Review

Recommended Practices and Best Available Control Measures – BACM

Dust Suppressant Selection Guides

A Manual

Recycled/Recyclable • Printed with Vegetable Oil Based Inks on 50% Recycled Paper (20% Postconsumer)

prepared for:
Industries of the Future
Converse Area
New Development

October, 2004

by:

Temple Stevenson

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Introduction

Fugitive **dust** emissions are increasingly becoming a problem for Wyoming's surfac mines located in a windy semi-arid environment where the average wind speed is 1 miles per hour and the average rainfall is a mere 14 inches with some of the highest evaporation rates in the nation. Fugitive **dust** emissions are a nuisance in coal mine impairs visibility, affects the health of employees, increases wear and tear of equipn and increases road maintenance and costs. Current drought conditions, elevated win speeds, compliance with air quality and clarity standards impacted by particulate emissions, a predicted increase in coal production, and increased Coal Bed Methane operations has heightened the concern.

Dust from surface coal mine operations also has the potential to negatively impact Federal Class I Air Quality Areas in the region, such as Badlands and Wind Cave National Parks and the Northern Cheyenne American Indian Area. While no visibili impairment in these Class I areas is currently attributable to any Wyoming source, i

anticipated that strategies to maintain a status of minimal impact will be of notable \
to the Western Regional Air Partnership (WRAP) and the State of Wyoming in the development of its Regional Haze SIP(State Implementation Plan), due by Dec 31, : (Wyoming's Long Term Strategy for Visibility Protection: Review Report, 2003).

It is the intent of this report to contribute to a better understanding of fugitive **dust** a mitigation, so that efficient and effective management strategies for suppressing it c implemented. The report includes four segments: I. Literature Review; II. Recomme Practices and Best Available Control Measures -BACM; III. **Dust** Control Suppress Selection Guides; and an Appendices containing a fugitive **dust** bibliography and document examples.

I. Literature Review: Fugitive Dust and its Control

Sources and Impact of **Dust** Generated by Surface Coal Mines

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Haul roads, over-burden piles, drilling and blasting, coal transfers and loading, and topsoil handling are all contributing factors of **dust** generation in a coal mine. A South African study conducted in an arid climate similar to Wyoming's by Thompson and Visser (2002) titled "*Benchmarking and Management of Fugitive **Dust** Emissions From Surface Mine Haul Roads*," determined that 93% of the total **dust** emissions from a coal strip mine could be contributed to coal transport or haul roads Figure 1. illustrates their findings of the contributions of specific sources of fugitive as a percentage of the total fugitive **dust** generated by a surface coal mine.

Fig. 1 Percentage contribution to total dust emissions (Thompson & Visser 2002)

Assessing the source and impact of **dust** to determine the need to increase watering, decrease speed, use **dust** suppressing chemicals (also known as palliatives), or re-graveling is constricted by a lack of problem solving methodology that takes into ac the complexity of various interactions. The interactions include traffic volume, weig climate, and more according to Thompson & Visser (2002). They add, "most surfac mine operators agree that **dust** free roads are desirable, but find it difficult to transla mine operators agree that **dust**-free roads are desirable, but find it difficult to transla into cost-effective management and mitigation." This same study found that regular watering and the application of chemical **suppressants** in conjunction with optimal aggregate surfaces is the only effective option for controlling fugitive **dust** emission haul roads.

The most harmful types of fugitive **dust** to the respiratory system are those that are 10 microns in diameter, known as PM_{10}'s. Because they are most harmful, they

most monitored. Another common measurement involves total suspended particulat TSP's. Total suspended particulates refer to the total amount of solid particulates an liquid droplets suspended in the air, regardless of particle size (Ferguson et al., 199 Wyoming has been monitoring PM_{10} emissions to meet Federal standards since before that TSP's were the only monitored emission.

> *According to EPA officials, exceedences of the 24 hour standard for particulate matter in southern Campbell County escalated substantially over the last 15 years; from 0 incidents during 1990-2000 to 19 incidents from 2001-03.*

Dust Suppression Planning

When a coal mine is in the process of implementing a **dust** suppression plan, cost ar plays a large role in product selection. When looking at a product, an overall cost an should be taken into account. According to Bolander and Yamada (1999) in a report the US Forest Service entitled "***Dust Palliative Selection and Application Guide***," a successful **dust** control program should not only reduce total **dust** emissions, but it also reduce maintenance costs. Some **dust** control products have proven that they ca significantly reduce overall road maintenance costs and thus achieve an overall savi At the same time additional preparation and a change in maintenance practices must accounted for. A booklet published by Environment Australia, a branch of Australia Department of the Environment and Heritage, ***Dust** Control Best Practice Environn Management in Mining (1998)*, explains the benefit of a **dust** control plan as "a long view of **dust** control has proven consistently cost effective. Mine planning has a particularly important role to play in **dust** control. Applying controls after the probl arise is often difficult, impractical or costly."

Haul Roads/Unpaved Roads

Fugitive **dust** is derived from a variety of sources; nonpoint sources such as un-vege soils, and specific sources such as haul roads (Environment Australia 1998). **Dust** generation can be defined as the process by which particulate matter becomes airbo The amount of **dust** that becomes airborne is a function of various factors; including susceptibility of the surface material to wind and water erosion, and the erosive acti of haul trucks (Thompson & Visser 2002). If this latter human activity coincides wi unfavorable weather conditions, the result can be greatly increased **dust** emissions (Ferguson et al., 1999).

> *Haul roads generate significant amounts of **dust** emissions (EPA Fugitive L 1992; Thompson and Visser, 2002).*

There have been several studies completed to estimate the emission rates of PM unpaved roads. According to Bolander and Yamada (1999) in the US Forest Sevice Report, ***Dust Palliative Selection and Application Guide,*** the followin **dust** generation factors should be considered when designing a **dust** control plan:

Dust Generation Factors:

- Vehicle Speed
- Number of Wheels Per Vehicle
- Traffic Volume
- Particle Size Distribution of the Aggregate
- Compaction of the Surface Material
- Surface Moisture
- Climate

Researchers from the Desert Research Institute at the University of Nevada determi that a vehicle traveling on a untreated unpaved road at a speed of approximately 25 generates between 0.59 to 2.00 lbs of PM $_{10}$ emissions per vehicle miles travele (Gillies et al. 1999). When that vehicle's speed was increased to 35 mph the emissic rates increased to 1.85 to 3.04 lbs. PM $_{10}$ VMT with an uncertainty of 0.23 lbs. VMT. Other studies have found similar emission results. Flocchini et al.(1994) sugg that reducing vehicle travel speeds on unpaved roads from 40km/hr to 24 km/hr red PM $_{10}$ emissions by 42 + 35%

The Environmental Protection Agency, reporting in *Compilation of Air Pollutants Emission Factors Volume 1 Ch 13, AP-42 (1998)*, found that emission of fugitive d haul roads is highly correlated with vehicle weight and silt content of the surface material. The study reported that a silt content mean of 8.4% of fines on a haul road a mean of 24% was found on a freshly graded haul road. This indicates a significant increase in fines after a road has been graded.

In addition to these factors the EPA also suggests that other traffic characteristics sh be considered: such as the cornering of trucks, the road's bearing strength, and grad (EPA, 1998, AP-42). They also suggest a complete examination into climate conditi like freeze/thaw cycles and monthly average wind speeds.

Effective **dust** control on haul roads in the Powder River Basin is complicated by th that stretches of road, constructed of less than optimal aggregates, are subject to hig traffic volume by heavy haul trucks, which requires continuous grading and the freq addition of new surface material. Wearing of surface material is related to a number factors including wind speed at the road surface, traffic volume and tonnage, type o aggregate, compaction of the road, amount of spillage, and climate (Thompson & V 2002).

In addition to haul roads and related travel areas such as truck parking lots, stockpile/reclaim areas also contribute to total **dust** emissions, but are usually much difficult to control. (EPA Fugitive **Dust**, 1992). The EPA has devised numerous equations to estimate emissions both from unpaved roads and from storage piles. Th equations can be found in "*Fugitive **Dust** Background Document and Technical Information Document for Best Available Control Measures*," published by the EP September of 1992.

In a report by the U.S Army Construction Engineering Research Laboratories Gebh al.(1999) noted that chemical **suppressants** should be considered as a *secondary so* in controlling **dust**. "A properly maintained road with adequate drainage to create a road surface should be the first step and must be implemented to the greatest extent possible. The best way to avoid a **dust** problem is to properly maintain the surface, that is achieved by grading and shaping for cross sectional crowning which prevents generation caused by excessive road surface wear." It should be noted that this stud to contend with heavy vehicles with tracks, such as tanks, which reduced the efficie and cost effectiveness of any **dust** suppressant.

Effectiveness of **Dust** Suppressant Measures on Unpaved Roads

When analyzing **dust** control effectiveness it is hard to determine a product's direct impact due to the large number of compounding variables (traffic volume, truck weight and speed, road type, etc.). This is further compounded by the fact that there is not a uniform standard for determining **dust** suppressant effectiveness (North Carolina Department of Environment and Natural Resources Division of Air Quality (2003). Most assessments available are based on qualitative data not quantitative data (Sanders & Addo, 1993). "Without any quantitative **dust** measurement, it is difficult if not impossible to assess the economics and lasting value of **dust** palliation methods," (Sanders & Addo, p.11, 1993). There are generally two areas of study concerning measuring or analyzing **dust**. The first is atmospheric modeling and prediction, and the second is field measurements and quantifications (Sanders & Ad 1993). Field studies are generally more helpful in determining actual effectiveness; however there are numerous factors that need to be considered. Because of the dive of site characteristics, it is difficult to recommend a suppressant that will work well situations.

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In many instances the only gauge of the effectiveness of a product is either the resul from manufacturer's testing or testimonials from previous users (Engle, 2004). Eve it is hard to determine if the product is going to work in a particular area with possi different aggregate type.

*The following is a summary of some of the significant studies that have been conduc regarding the relative effectiveness of **dust** control measures.*

Thomas Sanders, et al.(1997) conducted a study at Colorado State University on un road sections in Larimer County, Colorado to try to determine the relative effectiver of the three commercially available **dust suppressants**. These researchers evaluatec effectiveness of lignosulfonate (lignin'), calcium chloride ($CaCl_2$), and magr chloride ($MgCl_2$) against a section left untreated. They based their evaluation on th fundamental measurements: traffic volume, fugitive **dust** emissions, and total aggre loss and used these measurements to calculate a cost analysis.

After taking 15 **dust** samples over a test period of 4.5 months they found that all thr the treated sections outperformed the untreated section. Total aggregate loss was significantly higher for the untreated section, in fact it was 3 times more than the M 2.7 times the lignin', and 2 times the $CaCl_2$. Relative fugitive **dust** emissions v highest on the untreated section. Based on cost to replace aggregate lost, traffic volu cost of maintenance, and cost of **suppressants** they concluded that lignin' and MgC an identical cost per mile per year of $21 vehicle, while $CaCl_2$ was at $26 ar untreated was up to $36. They produced the following chart to highlight the cost an (ADT is the average daily traffic).

(Sanders, et al. p. 396, 1997)

Based on these results, the group concluded that under high temperature and low rel humidity lignosulfonate appears to lessen the amount of **dust** produced. They also f that lignosulfonate and $MgCl_2$ had the least total aggregate loss at 1.0 t/mi/yr/ve study found a 28-42% reduction in annual maintenance cost for the treated sections compared to the untreated sections.

> However, during a personal interview with this author on March 30, 2004, Sanders stated that he felt the $MgCl_2$ was the superior product based o long term effectiveness (Sanders, 2004).

In a laboratory study, Epps and Ehsan (2002) compared aggregates from Wyoming, Texas, and Arizona to determine the effectiveness of water, $CaCl_2$ and MgC controlling **dust**. They used a crushed gravel stone from Wyoming in one segment study. This gravel contained approximately 9.9% fines, less than both the Texas and Arizona samples. They prepped the aggregates by allowing them to cure for 2 days 32C and 35% relative humidity. They then sprayed the samples with water at a rate 1.8 L/m^2 to reduce the surface tension and increase the rate of penetration, and nex applied magnesium chloride to one sample, calcium chloride to another, and water to another sample. They found that applying chemical palliatives ($MgCl_2$ the Wyoming aggregate had a statistically significantly effect on reducing erosion c by wind. This, they determined was related to the fact that the chemicals kept the su wet even in windy conditions. The authors found no real difference between the Mg and $CaCl_2$, but noted that both lose their effectiveness over time.

Next they evaluated the effectiveness of the chemicals in a simulated traffic experin They found that a 38% solution of $CaCl_2$ and a 30% solution of $MgCl_2$ app

Wyoming aggregate significantly reduced erosion caused by traffic compared to an aggregate sample that was only treated with water. They concluded that the applicat of $CaCl_2$ or $MgCl_2$ greatly enhanced **dust** control on unpaved roads in compariso water or no treatment and that there is not a significant difference between the two chemicals.

Gillies et al. (1999) from the Desert Research Institute at the University of Nevada a the San Joaquin Valley Unified Air Pollution Control District evaluated the effectiv of four **dust suppressants** over a 14 month study. The **suppressants** that were teste included a biocatalyst stabilizer (EMC^2), a polymer emulsion (Soil Sement), a emulsion with polymer (Choerex PM), and a nonhazardous crude-oil-containing ma The study identified an equation to calculate suppressant control efficiency, which t define as "the percent reduction in emissions between the treated and untreated secti

Efficiency= 1-(treated emission factor/untreated emission factor)

This study determined that estimating suppressant efficiency can be done using som simple methods in place of expensive monitoring. The authors determined that a measurement of the bulk silt loading and the surface strength can provide an effecti inexpensive assessment of a **suppressants** effectiveness to reduce PM_{10} emi *suppressant treated surface that can achieve bulk silt content less that 20 g/m2 is considered to be 90% effective at suppressing* PM_{10} *emissions*. Further, if tha maintain flexibility (measured by a penetrometer) and can resist brittle failure then t suppressant is predicted to maintain effectiveness longer (Gillies, et al. 1999).

> Effectiveness results The bio-catalyst (EMC^2) was only 39% effecti after the initial application and 0% effective after 11 months. The acrylic co polymer was 95% effective after one week and approximately 85% after 11 months. The bitumen product was 95% effective after one week, 75% after months, and 53% after 11 months.

The EPA has created an equation to determine the PM_{10} emission factor for u roads. This accuracy of this equation, however, is still under some question, particul related to vehicle speed (**Muleski/MRI 2002**). *Also this equation is designed aroun* *average traffic weight, and does not account for heavier trucks (e.g. haul trucks).*

$$E=2.6\ (\mathrm{Silt}/12)^{0.8}\ (\mathrm{Weight}/3)^{0.4}\ /\ (\mathrm{Moisture}/0.2)^{0.3})$$

E = PM $_{10}$ unpaved road **dust** emission factor for all vehicle
Silt = silt content, material less than 75 μm in the surface mater
Weight = average weight of the vehicle fleet (tons)
Moisture = surface moisture content (%) *(EPA, AP*

The addition of moisture into the equation is fairly recent (Countess, 2001). It was a based on the recognition that climate and moisture play a large part in overall emiss from unpaved roads. An older version of this equation included variables for the nu of wheels and speed, but re-analysis proved the variable not to be statistically signif (Countess, 2001). However, when using this model in an industrial setting it may be important to account for total wheels, traffic volume, and speed as variables. In addi some feel that the type of aggregate should be included as it can often account for th long term amount of fines in the road surface.

Dust Suppressants

Road **dust suppressants** have evolved notably. Second and third generation produc now solving not only the **dust** problem but also cost efficiency, environmental, and issues (Engle, 2004). Positive results are now coming from even the toughest desert drought environments where past products have failed (Engle, 2004). While EPA (42, 1998) testing has shown that chemical **dust suppressants** can be effective (80% reduction when applied at regular intervals) there is not a single, cure-all solution. S products work better in certain climates, various road surfaces, and under different t volumes, and each product comes with various advantages and limitations.

Dust suppressants are effective based on the fact that they agglomerate the fine pa in a road surface, binding the surface particles together, and increasing the density o haul road surface material (Bolander & Yamada, 1999). If fines are lost as **dust** on unpaved road it leads to the coarse material coming loose and can then be thrown or washed away. This can result in a road full of corrugations and potholes that require expensive maintenance (Sanders & Addo, 1993). "The main goal of a **dust** control i stabilize the road surface; reducing the rate of aggregate loss and money spent annu replacement," (Sanders & Addo, 1993).

Dust control additives are beneficial not only at reducing **dust** emissions, but they a improve the compaction and stability of the road. According to Epps and Ehsan (20 there are numerous factors related to the effectiveness of a **dust** palliative including application rate, method of application, moisture content of the surface material dur application, palliative concentrations fines content, mineralogy of the aggregate, an environmental conditions.

Surface treatments to control **dust** emissions fall under two categories. wet suppress and chemical stabilization (EPA. AP-42. 1998). Wet suppression includes watering the application of surfactants that keep the road surface wet. Chemical stabilization involves an attempt to change the physical characteristic of the road. Unlike waterin chemical **suppressants** require less reapplication and many act to form a hardened r surface (EPA. AP-42. 1998).

The addition of a wetting agent or larger sized particles reduces erodibility only at tl interface of the surface and the impact vehicles (Thompson & Visser 2002). **Dust** cc measures lose effectiveness on a scale ranging from immediately to weeks. The palliative effects of water decays from 100% to 0% in a matter of hours while chem applied to control **dust** may decay over several days or weeks so it is important to understand the expected effectiveness of the product that you are working with (Thompson & Visser 2002).

A report issued by the U.S. Department of Transportation and the South Dakota Loc Transportation Assistance Program states that in areas of high traffic volume, the co **dust** control can more than pay for itself. This is based on the fact that a good **dust** (agent can not only reduce material lost from the road. but also reduce the need for b maintenance (Skoreth & Selim 2000). The same study determined that when a **dust** suppressant is not working well aggregate fines are lost. leaving only gravel size pa on the road. which leads to the formation of a washboard surface. reduced skid resis and potholes. The addition of agents (water or chemical) to reduce erodibility is bas the principle of increasing binding of the fines and gravel. (Thompson & Visser 200

According to "Surface Mine **Dust** Control" by John Organiscak. et al. (2003). the be **dust** control plan should be dependent on the type of aggregate you have on your ha road. Selecting a **dust** suppressant. according to Sanders (1993) should depend not c on its performance characteristics. but also on the type of traffic and volume, roadw conditions. and the costs involved to achieve the desired level of control.

In the following selection and application guide. Bolander and Yamada (1999) sugg that selecting **suppressants** involves determining not only cost but cost effectivenes

They have devised the following list of benefiting factors that should be considered selecting a **dust** palliative.

Palliative Factors

- Coherence of the **Dust** Particles (to themselves or larger parti
- Resistance to Traffic Wear
- Aggregate Retention
- Long-term Effectiveness

(Bolander & Yamada, 19

Water

Water assists in maintaining the compaction and strength of the road aggreg and reduces the potential loss of road material (Thompson & Visser 2002). is attractive because it is seen as a cost effective alternative, however the co soon escalates with the addition of expensive equipment and operating cost

Data from the EPA's *Compilation of Air Pollution Emission Factors Volum Ch 13, AP-42* (1998) shown here in Figure 1.1 suggests that small increases moisture content (1 to 2 moisture level) initially results in large increases in control efficiency (from 0% to 75%) but beyond which additional efficienc grows slowly with increased watering (requires 2.5x more water to increase effectiveness to 95%) significantly reducing cost effectiveness at the upper

Figure 1.1 Dust Control Efficiency of Water

Similarly, a study by Rosbury and Zimmer (1983) found that watering once hour has an efficiency of 40% in controlling **dust**, but when that rate is dou the efficiency increases only by 15% to 55%.

Re-application is required at frequent intervals dependent on environmental conditions. Water retention in the Powder River Basin is generally poor due high temperatures and wind speeds as well as low relative humidity. Increa

water scarcity and cost adds to the scenario making water a temporary and typically un-economical solution.

Thompson and Visser (2002), based on the context of the arid South Africa mines, determined the degree of **dust** control achieved by watering is a func the amount of water applied, time between applications, traffic volumes, we conditions, wearing-course material, and the extent of water penetration int

wearing course. They determined that on an average degree of dustiness, a
reapplication is required at three hour intervals in the winter and every hour
half in the summer. These intervals decrease with the addition of weight pe
vehicle, number of wheels, traffic volume, and climate conditions.

Thompson and Visser (2002) also found that traffic volume negatively corr
with total dustiness; which they explained based on observation, that highe
volumes led to more compaction of the wearing course and the removal of
loose material on the sides of the road as well as spillage from the vehicle.
also determined that vehicles lower to the ground with many wheels tend to
an increase in **dust** based on the increase in wind shear.

Precipitation can greatly reduce **dust** emissions. Normally a rainfall resulti
least 0.1 inch is assumed to suppress all emissions. However during a hot, d
summer's day a rain of that same amount may only reduce emissions for h
opposed to days (Countess, 2001).

Chlorides

Chlorides are salts that act as water attracters and absorbers; as hygroscopic
compounds, they draw moisture out of the air to keep the road surface dam
although there is no physical binding (Skoreth & Selim 2000).

> *Chlorides are the most commonly used products for haul road* ***dust*** *control. A study by Rosbury and Zimmer (1983) showed that the highest control efficiency measured for a chemical* ***dust*** *suppressant (at that time), 82%, was for* $CaCl_2$ *two weeks after*
> *then decreased over time. The average during the initial two weeks was approximately 50%. After five weeks, the control efficiency declined to less than 20%.*

The most common salts used to control **dust** are calcium chloride (CaCl
magnesium chloride ($MgCl_2$). When determining which is most effectiv
ability to produce a brine under adverse conditions such as high wind speed
humidity, or high traffic volumes is the best indicator (Sanders, 1993).

$CaCl_2$

Calcium Chloride ($CaCl_2$)has been used as a **dust** control and r
stabilizing agent for the last century (Epps & Ehsan, 2002). CaCl
deliquescent and hygroscopic properties causing the chemical to ha

high affinity to water; increasing the tension of water molecules be soil particles. When applied the chemical increases the adhesive bo between particles resulting in retention of particles. According to E al.(2002) $CaCl_2$ has a wider range of effectiveness in regards to temperature than magnesium chloride and loses its hygroscopic prc at a temperature of 25C if the relative humidity drops below 32%.

Calcium Chloride comes in three forms: flake at 77-80% purity, pe 97% purity, and a clear liquid at 35-38% purity (Bolander & Yama 1999). Calcium Chloride is favored over Magnesium Chloride in a seasons of higher humidity, but it is not as effective in long dry spe (Bolander & Yamada, 1999). This chemical can significantly lowe freezing point of a water solution. In fact at 30% solution can have freezing point of -60F (Larkin Laboratory, 1986). Because of this property several coal mines choose to use $CaCl_2$ during the w

$MgCl_2$

Magnesium chloride is a by-product of potash production and is on available in the liquid form (Ferguson et al., 1999). When determin $CaCl_2$ or $MgCl_2$ is more effective there are contradictory finding statements. It seems the more recent studies are coming to the conc the $MgCl_2$ is outperforming $CaCl_2$. According to Epps and Esh $MgCl_2$ is more effective than $CaCl_2$ in increasing the surface te water molecules. Bolander and Yamada (1999) found that MgCl considered to be the best water absorbing product for drier climate because the chemical starts to absorb water from the air at 32% rel humidity regardless of the temperature. The product also increases aggregate surface tension, creating a very hard road when the surfa dry, more so than $CaCl_2$

Both $CaCl_2$ and $MgCl_2$ are known to be corrosive to metals, because the moisture to the surface and thus prolong the period of erosion (Bolander & Yamada, 1999). A positive attribute of both of these chemicals is that each allows a maintenance crew to re-grade and re-compact with little concern f surface moisture loss.

Gebhart et al (1999) state that these salts provide the most satisfactory blen

Gebhart et al.(1999) state that these salts provide the most satisfactory blen application ease, cost, and **dust** control for semi-arid, semi-humid climates.

Organic/Non-Bituminous Chemicals

Compounds under this category include lignosulfonate, sulphite liquors, tal pitch, pine tar, and vegetable oils. These products generally perform well in environments but are not very effective when applied to aggregate surface material with few fines (Gebhart, et al., 1999). These **dust** control agents ca

very sticky and may harbor an unappealing odor. They often fail after heav due to their water soluble, organic nature (Gebhart, et al., 1999). These proc currently appear expensive, but the cost benefit equation continually change a rule, they tend to be environmentally friendly. One compound with some supporting literature is lignosulfonate (lignin').

Lignin'

Lignin' or lignosulfonate is a by-product of the paper making proce is regarded to be generally safe environmentally because of the fac is an organic product. This product performs very well under arid conditions. It binds particles together to increase the strength of the and remains effective during long dry spells with low humidity (Bc & Yamada, 1999). One of lignin's weaknesses is that it is highly sc in water, and its surface binding properties can be destroyed by hea It also has a tendency to stick to passing vehicles and is difficult to from painted surfaces (Frazer, 2003). Lignin is most effective and s the greatest longevity when the road has been scarified and the pro been mixed into the aggregate (Sanders & Addo, 1997). However, this same scarification process that reduces the current use of ligni some haul roads, as the perceived costs of the down-time due to scarification and curing appears prohibitive.

A study using lignin' on Pikes Peak's unpaved roads conducted by

Sanders and Addo (1998) revealed that the lignin was 2.7 more eff at suppressing dust than water. After spring snowmelt. 8 months af application. there were indications that the Lignin' was still functio a good proportion of the test sections.

Petroleum Products

Petroleum products include asphalt emulsions (modified and not). dust oils fluids. and petroleum resin emulsions. These products may be effective in a variety of climates; however. because they are by-products of petroleum an waste oils. they may contain toxic materials with significant environmental effects. and are not considered safe unless they have been processed to rem toxins (Gebhart. et al., 1999). These products are usually very expensive an the organic products. are very sticky and have a foul smell.

Petroleum products are film forming and dust binding. They coat the dust particles and form a cohesive membrane that attaches each to adjacent parti This results in a chained bond of large agglomerates that are too heavy to b dislodged by wind (James Informational Media. Inc., 2000).

Emulsified Asphalts

Emulsified Asphalts work to control dust. but their use is very limi the product must be applied with specialized equipment (Skorseth Selim 2000). The soil type and density of the road surface can grea affect the rate at which a petroleum product penetrates the road. Rc that have been scarified to loosen the aggregate achieve the greates amount of soil penetration. If the road has not been scarified the us products with low viscosities will be ineffective (Bolander. Yamad 1999).

Polymers

Polymers such as polyvinyl acrylics and acetates work by binding the surfa particles together to form a semi-rigid film on the surface. Polymers are considered suitable for use under a wide range of climate and soil condition are most effective in environments that receive 8 to 40 inches of precipitati year. Generally, a light compaction of the road after application of a polym recommended unless the product is mixed into the road surface (Bolander, Yamada 1999). Polymers are considered to be most effective on *lightly traf areas*. These types of palliatives are usually non-toxic and environmentally friendly (Gebhart, et al., 1999).

Electro-Chemical Stabilizers

Electro-Chemical stabilizers include sulphonated petroleum, ionic stabilize and bentonite. They are not likely to leach out and are stated to be very effe at reducing **dust** emissions in clay or sandy aggregate types. These product well under a variety of climate conditions; however, many of these product not been tested using standard laboratory tests under field conditions. Small trials should be performed to determine site specific efficiency prior to larg scale usage (Gebhart, et al., 1999).

Surfactants

Essentially surfactants are additives that make water wetter, reduce surface tension allow better penetration of the palliative. At least one product (Haul Road **Dust** Con claims a cumulative effect, whereby each new application boosts the effectiveness o previous levels.

Several manufacturers of surfactants recommend prewetting of the roadbed, for thei products to perform optimally. Similarly, Epps and Ehsan (2002) used prewetting in their laboratory study of aggregates and erosion.

There is a slight trend within mine operations in the Powder River Basin to use high diluted applications of $MgCl_2$ and $CaCl_2$ in all water applications, instead of a

There are environmental concerns associated with the use of certain surfactants. (ref
page 17 of this document for a discussion of these impacts)

Other Commercial Products

A list of commercial products is posted by The New Mexico Environment/ Departm
of Air Quality Bureau, which can be accessed on the web at
http://www.nmenv.state.nm.us/aqb/dust_control.html and in Table 3.1 of this report
There are some products listed here that are not included in this literature review.
Classification of every product is not possible in part due to lack of a literature histo
and to the proprietary nature of the commercial formulas.

Mechanical Stabilization

Mechanical or road stabilization is the mixing of two or more substrate materials to
a road surface that has the correct fine gradient and plasticity. This method does not
involve the application of chemicals although they can be used in addition to the
stabilization. One of the most effective substrate mixtures involves the addition of c
to a gravel and sand aggregate. The clay binds to the fine particles, and improves th
roads stability and longevity. "When a gravel road resists lateral displacement durin
traffic, it is said to be mechanically stable, notes Gebhart, et al. (1999). This resistan
provided by the natural forces of cohesion and internal friction that exist in the soil.'

Importance of Appropriate Dust Suppressant Application

Appropriate application of a selected product is key to the overall effectiveness of a
control plan. "It can translate either into success or costly wastefulness, failure, and
difficult maintenance down the line." according to David Engle (2004), author of "
Maintenance Techniques and Products Have Made Great Strides." Engle also
emphasizes timing as a critical component to successful application. He suggests an
initial application during the narrow window between the spring rains and the start
summer drought: "Keeping an eye on the weather forecast is critical: many expensi
applications have been ruined by rainfall."

Not only is the timing of the application crucial, but the manner in which the produc
applied is just as important - if not more so. Sanders and Addo (1993) describe two
in which suppressants are most typically applied: mixed-in-place and spray metho
The mixed in place method involves mixing the suppressants with the road aggreg
When this application procedure is used it not only suppresses dust but it also provi
for an improved road surface resulting in reduced maintenance costs. Spraying invo
the high pressure application of the material to the road surface. Topical spraying is
effective for short periods of time, though, resulting in the need for reapplications.

effective for short periods of time, though, resulting in the need for reapplications throughout the season (Sanders & Addo, 1997). It is usually wise to try a test sectio determine how well the product is going to work on a specific gravel, and what type application works best (Skorseth & Selim, 2000).

> *Almost all suppressants have a greater longevity and effectiveness when applied to a road that has been properly prepared, scarified, and the suppressant is mixed in with the aggregate and then compacted to a 6-inch thick wearing course (Sanders & Addo, 1997).*

Another key application principle was identified by Bolander and Yamada (1999). suggest that adequate penetration of the **dust** suppressant into the surface material i imperative. This penetration should be 3/8 to 3/4 of an inch in depth. Proper penetra will reduce the loss of palliative from surface wear and allow the surface to resist leaching. The process imparts cohesion, and resists aging.

Bolander and Yamada (1999) in the *USFS* ***Dust Palliative Selection and Applicatio*** provide the following suggestions for applying **dust suppressants**:

Application Tips

- Repair unstable surface, grade (to a adequate depth) immediately to application
- Apply **suppressants** (especially salts) immediately after the wet
- Apply after a rain, or spray the road before application, to ensure materials are more moist and thus more workable
- Adhere to manufactures recommendations on minimum applicati rate, compaction and curing time
- Use a pressure distributor to evenly distribute the suppressant
- Water frequently and lightly, not infrequently and heavily

Scarifying

Sanders et al. (1997) include scarification of the road surface in their list of important techniques to be considered when applying **dust suppressants** a particularly specify the technique when using lignin. Organiscak et al. (200 suggest that when using chlorides it is beneficial to loosen 1-2 inches of the aggregate uniformly to allow the chemical to penetrate evenly. And like Bo

> and Yamada (1999). the group stresses proper road preparation as a key to t effectiveness of a **dust** palliative. especially creating a good crown and drai when using a chloride. They also state that when using a chloride the roadw should not be compacted before applying the chemicals and the road shoul kept at optimum moisture before application. this allows the product to be absorbed quickly and evenly.

For some **suppressants** it is recommended to keep traffic off the road surface for tw three hours after application to allow the product to absorb and cure (Skorseth & Se 2000). This characteristic is expected to be considered a limitation by mine enginee who would have difficulty justifying the necessary down time involved on mine ha roads (see survey results. Appendix A). Grading after application also partially dest the effect of many **dust suppressants** (Ferguson et al.. 1999). Because of this, gradi should be postponed after heavy application of suppressant for as long as possible.

The EPA has recommended that a diluted reapplication be applied periodically (2 w to a month) to control loose surface material. They also state that weather related

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application schedules should be considered prior to implementing a **dust** control pr (EPA Fugitive **Dust**. 1992).

The type of road aggregate is one factor that determines the type of **dust** control tha most effective. Organiscak et al. (2003) recommend effective applications for vario road types in their article "Surface Mine **Dust** Control." In road surfaces with poor gradation. water is the only effective solution because chemical **suppressants** (mos which are water soluble) cannot compact the surface or form a new surface because will leach. In sand they recommend bitumens because of the fact that they are not w soluble. On a road with good gradation all chemical **suppressants** can be used, and road with too much silt the road should just be rebuilt, as no **dust** control will be eff (Organiscak. et al.. 2003). If a haul road is left untreated by a **dust** suppressant aggr replacement will become necessary over shorter periods of time and maintenance w required more frequently (Epps & Ehsan. 2002).

Education and Training

In addition to using prescribed application procedures, John Watson and Ju Chow (2000) from the Desert Research Institute suggest that the success of control problem depends on outreach and education programs for contracto public works agencies. In a coal mine, education should be extended to maintenance personnel.

Environmental Impacts

The major environmental concern when using **dust suppressants** is contamination ground and surface water. Thomas Piechota, an assistant engineering professor at University of Nevada Las Vegas was quoted in Lance Frazer's "*Down with Road D (Innovations)*" as saying it doesn't matter what suppressant is used, there will alway some level of water quality impact (Frazer, 2003). Peichota noted that petroleum compounds were more harmful than **suppressants** such as magnesium chloride. An area of impact he mentioned is the fact that the **suppressants** are creating a somewh impenetrable road surface, which will increase runoff, which has its own hydrologic impacts.

There is some potential for off-site plant damage during periods of heavy rainfall (Ferguson et al., 1999). All necessary precautions should be followed to unsure that chemicals are kept away from water sources.

The following photo taken in June of 2004 in Larimer County, Colorado between L and Estes Park strongly suggests runoff from a highway treated with a 30% solution and Estes Park strongly suggests runoff from a highway treated with a [illegible] solution Sodium Chloride (rock salt) and sand may be impacting ponderosa and other pines (Anon' CoDOT, 2004).

While no Wyoming coal mines use Sodium Chloride to treat **dust** on haul roads tha know of, the expected negative publicity from this environmental impact (near Boul may carryover into other road salts such as $MgCl_2$ and $CaCl_2$ which are heav There is no scientific evidence yet of the actual cause of the tree damage, but the die appears to be confined to an area within 50' of the roadway for 20 plus miles, strong suggesting road runoff and/or exhaust fumes as contributing factors. Conversely, fe Wyoming coal mine haul roads traverse timbered acreage, limiting this specific imp

Surfactants, on the other hand, may pose some environmental concerns. M. Warhur (1995) in a report to Friends of the Earth, England, outlines toxicity concerns with alkylphenol ethoxylate (APEO) surfactants, and calls for a more widespread ban on use (The surfactant is currently banned in several European countries). He recomme the replacement of APEOs with linear alcohol ethoxylate surfactants, which are reac biodegradable according to Consultants in Environmental Sciences Ltd (CES, 1993

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