Dust Suppressant Use and Alternatives at Carnegie State Vehicular Recreation Area

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Introduction

The intent of this report is to describe the current use of magnesium chloride as a dust suppressant at Carnegie State Vehicular Recreational Area (the Park) and investigate potential alternatives. The emphasis of this literary research is on the relationship between the dust suppressants described and the potential effects on storm water quality.

Problem Statement

Of the 3,800,000 miles of roads in the continental United States, over 1,700,000 miles are unpaved roads (Sanders & Addo 1993, Piechota et al. 2004). Dust from unpaved roads is the largest source of particulate air pollution in the country (WTIC, 1997). This is a concern since fugitive dust can have many undesirable effects including impacts to human health, the environment, aesthetics, and the economy. In general, the stability of road surfaces relies on both small and large material for stabilization. The small material acts as a binder for the larger material. The abrasive nature of vehicular traffic dislodges and fractures the surface material making it susceptible to mobilization from wind and water. The smaller the material the easier it is mobilized. Fines that are not even visible to the human eye are still critical to maintaining the integrity of the road surface. Once the smaller material erodes, the larger particles loosen, leaving the road less stabile and more susceptible to wind and water erosion. Lones and Coree (2002) reported that an untreated road can lose up 300 tons of aggregate per mile per year.

Dust suppressants play an important role in minimizing the impacts that can occur on unpaved roads. There are many products used to suppress dust and most of the products used can be placed into several broad categories: water, salts/brines, organic non-petroleum, organic petroleum, or inorganic chemicals (Piechota et al., 2004). These varieties of dust suppressants work in different ways. Most of the products agglomerate the particles, making big particles from smaller ones. This occurs by either creating moisture tension between fine particles (hygroscopic), cementing the particles (chemicals), or altering the surface chemistry (surfactants). The use of dust suppressants is widespread in the U.S. Of the over 1,500,000 miles of public unpaved roads in the nation, approximately 25 percent are treated with a dust suppressant product. Of the approximately 211,000 miles of private unpaved roads, 22 percent are treated with a dust suppressant product (Piechota et al., 2004). In 1991, it was estimated that 75-80 percent of dust suppressants used were hygroscopic (salts), 10-15 percent were petroleum based, and 5-10 percent were organic non-petroleum (Piechota et al., 2004).

The Park is located in the San Joaquin Valley Air Pollution Control District (the Air District). During the 2001-03 reporting period, the Air District reported that particulate matter of 10 micrometers (PM10) and 2.5 micrometers (PM2.5) for the air basin exceeded the State and national standards numerous times and that fugitive dust was a major contributor. The report identified unpaved roads and agricultural sources (as well as “other”) as the leading contributors (CARB, 2012).

Site Description

The Park experiences a semi-arid Mediterranean-type climate with most precipitation falling between October and April. From spring until fall, marine air flows through the canyons into the San Joaquin Valley resulting in slightly-moderate temperatures. During the winter the relative humidity is about 85-90 percent at night and decreases to 60-70 percent during the afternoon. The driest part of the year is in the fall when humidity ranges from 30-50 percent. Annual precipitation averages nine inches.

For the past several years, the Park has applied magnesium chloride solution (Dust-off, Cargill Salt, Newark, CA) on the park road annually. The park road is approximately 3 miles in length with an average of 25 feet wide (21-46 feet range). The road is graded and the solution (125 tons) is applied using a spray boom in May or June. With nearly 79,000 annual visitation (J. Ramos, personal communication, May 25th 2012), the park road receives moderate use at low speeds from light weight motor vehicles and trailers. The road consists of native alluvium, gravel, and sand. Periodically, the surface of the road is capped with two inches of three-quarter minus road base. Since the introduction of magnesium chloride in 2006, the dust from the park road has been significantly reduced. In order to maintain effective moisture content levels, small amounts of water are applied on the road throughout the drier months (J. Mynk, personal communication, May 25th, 2012). The Dust-Off product contains 29-33 percent magnesium chloride, 1-4 percent magnesium sulfate, and 63-70 percent water (Cargill, 2010) and application rates are consistent with the manufactures recommendations.

Summary of Common Dust Suppressant Alternatives

This section's aim is to describe the more common and studied dust suppressants. Most of the research has focused on the salts, lignin, and organic petroleum products (Piechota et al., 2004).

Water

Water is a short term dust suppressant that agglomerates surface particles similar to chlorides. Unfortunately, the effectiveness is short lived and ranges from an half an hour to twelve hours (Piechota et al., 2004). For this reason and the limited supply of water at the Park, this is not considered a long term solution.

Chlorides and Brines

Chlorides are hygroscopic and are the most common dust control agent used on unpaved road surfaces (Piechota et al., 2004). Chlorides are ionic compounds that create strong attractions between each ion and the surrounding weakly magnetic water molecules. This attraction reduces the evaporation rate and allows the surface to retain water. Surface tension also increases which binds the dust particles together. The most common chlorides used are magnesium and calcium. Both of these salts will absorb water from the atmosphere as well (CPWA, 2005).

Magnesium Chloride

Magnesium chloride naturally occurs as brine or as a byproduct of potash production (WTIC, 1997). The magnesium chloride is produced only at three sites in the western United States (CPWA, 2005). Common product names are DustGard, Dust-off, and Chlor-tex.

Pros

- Effective at keeping aggregate stable and in place (Sanders et al. 1994)
- Very effective at reducing dust (Edvardsson, 2010; Sanders et al., 1994)
- Performs better than calcium chloride during long, dry spells (Bolander & Yamada, 1999)
- Cost effective when compared to paving and other dust suppressants (Edvardsson, 2010; Sanders et al., 1994)
- Last longer than lignin products (Edvardsson, 2010)
- Impacts to water quality are minimal and below USEPA thresholds (Goodrich et al. 2009, Shi et al. 2009)
- Not toxic to sensitive aquatic life (Edvardsson, 2010)
- Less toxic when compared to petroleum-based, acrylic polymers, and lignosulphonate products (Piechota et al., 2004)
- Reduces turbidity (Evardsson, 2010)
- Higher surface tension than calcium chloride (Piechota et al., 2004)
- Remains more hygroscopic at higher temperatures than calcium chloride (Piechota et al., 2004)

Cons

- Water soluble so application needs to occur annually (Bolander & Yamada, 1999)
- Leaching will likely occur (Goodrich et al., 2009)
- May be corrosive to steel (Bolander & Yamada, 1999)
- Concerns about impacts to sensitive plant species (Bolander & Yamada, 1999)
- Requires minimal humidity level (30 percent) to absorb air moisture (Bolander & Yamada, 1999)
- Surfaces with high fines may become slippery (Bolander & Yamada 1999)

Calcium Chloride

Calicium chloride is a byproduct of brine from manufacture of sodium carbonate and of bromine from natural brines (WTIC, 1997). Common product names include Calcium Chloride Liquid, Calcium Chloride Flakes, Dowflake, and Liquidow.

Pros

- Very effective at reducing dust (Edvardsson, 2010; Sanders et al., 1994)

- Cost effective when compared to paving and other dust suppressants (Edvardsson, 2010)
- Less toxic when compared to petroleum-based, acrylic polymers, and lignosulphonate products (Piechota et al., 2004)
- Reduces turbidity (Edvardsson, 2010)
- Performs better than magnesium chloride at high humidity (Bolander & Yamada, 1999)
- Last longer than lignin products (Edvardsson, 2010)

Cons

- Least effective at keeping aggregate stable and in place when compared to lignosulphonate and magnesium chloride (Sanders et al., 1994)
- Water soluble so application needs to occur annually (Bolander & Yamada, 1999)
- Highly corrosive to aluminum and its alloys (Bolander & Yamada, 1999)
- Surfaces with high fines may become slippery (Bolander & Yamada, 1999; Lohnes & Coree, 2002)
- Concerns about impacts to sensitive plant species (Bolander & Yamada, 1999)

Sodium Chloride

Sodium chloride is the common salt or table salt and is mass-produced by evaporating seawater or mining rock salt. Along with magnesium chloride and calcium chloride, it is commonly used for deicing. It has had limited use as a dust suppressant.

Pros

- Cheapest of the chlorides (CPWA, 2005)
- Good for mechanically stabilizing roads (CPWA, 2005)
- Improves moisture retention, freeze-thaw durability, traffic-ability and resisted erosion (Lohnes & Coree, 2002)

Cons

- Needs high humidity (75 percent) to absorb moisture from the atmosphere (Bolander & Yamada, 1999)
- When in solution it disperses fines (CPWA, 2005)
- When it dries particles become susceptible to wind erosion (CPWA, 2005)
- High concentrations found in storm water near roads (Goodrich et al., 2009)
- Concerns about impacts to sensitive plant species (Bolander & Yamada, 1999)
- Inferior to calcium and magnesium chloride as a dust suppressant (CPWA, 2005)

<u>Organic Non-petroleum Products</u>

These products include ligninsulfonate, tall oil, vegetable derivatives, and molasses. The ligninsulfonate products have been well studied while research on the other products remains limited, especially the impacts on aquatic habitats (Bolander & Yamada, 1999)

Lignosulphonate

Lignin naturally occurs in wood cells and is removed during the paper-pulping process. In plants, it gives strength to the wood cells. During processing, sodium, calcium, ammonium, or magnesium bisulfate is used to make the lignin soluble (CPWA, 2005). These products work best when incorporated into the first couple inches of the road surface (CPWA, 2005). Product common names include DC-22, Dustac, CalBinder, Lignin Sulfonate, Polybinder, and RB Ultra Plus.

Pros

- Effective at treating dust (Sanders & Addo, 1993)
- Effective at keeping aggregate stable and in place (Sanders et al., 1994)
- Cheaper than calcium chloride (Sanders et al., 1994)
- More effective in dry conditions (WTIC, 1997)

Cons

- May negatively affect dissolved oxygen levels since it is a derivative of wood (CWPA, 2005; Bolander & Yamada, 1999)
- Slippery when wet (WTIC, 1997)
- Brittle when dry (Edvardsson, 2010; WTIC, 1997)
- Highly acidic if unprocessed although uncommon (WTIC, 1997)
- Ground disturbance (mix in place) application may disturb cultural resources
- Long term, not as effective as the calcium and magnesium chloride (Edvardsson 2010; Sanders & Addo, 1993) resulting in more frequent applications (<1 year)
- May be corrosive to aluminum and its alloys (Withycombe & Dulla, 2006)
- In water bodies, high coloring effects, reduce biological activity, and retard growth in fish (Piechota et al. 2004)
- Heavy rains may destroy product (WTIC, 1997)
- May discolor paint of vehicles (WTIC, 1997)
- Can be odorous and sticky when applied (WTIC, 1997)
- Do not bind well to road surfaces previously treated with chloride products (Withycombe & Dulla, 2006)

<u>Organic Petroleum Products</u>

Due to the potentially high environmental impacts of organic petroleum products (Lohnes & Coree 2002; Piechota et al., 2004), the Park is not considering this a viable option for dust suppression.

Environmental Effects of Dust Suppressants

Storm Water Quality

Several articles suggest water quality concerns with dust suppressants (Bolander & Yamada, 1999; CPWA, 2005; Piechota et al., 2004; Sanders & Addo, 1993; Shi et al., 2009; Withycombe & Dulla, 2006). While the need for more research is recognized (Irwin et al., 2008; Piechota et al., 2004), a couple of studies have attempted to determine if dust suppressants are harmful to nearby surface waters.. For the most part, environmental studies have focused on salts, ligninsulfonates and a few organic petroleum products (Piechota et al. 2004).

One of the more thorough studies found regarding dust suppressants and water quality was in Colorado by Goodrich et al. (2009). This study's aim was to evaluate the effects of magnesium chloride on the chemistry of the nearby streams. Sixteen in-stream locations were sampled near unpaved roads where applications of both lignin and magnesium chloride were applied approximately one to three times each year. Water samples were collected biweekly. These sixteen locations were paired, one 20-50 m upstream and one 20-50 m downstream. While Goodrich et al. (2009) did find that magnesium chloride did migrate into the adjacent streams, not all downstream measurements were statistically different than those upstream and the researchers concluded a strong water quality response could not be established.

In a study highlighted by Piechota et al. (2004), several products were tested for leaching effects including acrylic polymer emulsion, ligninsulfonate, petroleum-based non-organic, non-petroleum based organic, fiber mulch and magnesium chloride. The researchers simulated rain fall on plots 2.4 m x 2.4 meter in size. The first 5 gal of runoff was collected as well as the top 2 inches of soils was analyzed to see which compounds remained. The researchers measured several parameters including "67 toxic volatile and 76 semi-volatile organic compounds, organic pesticides, PCBs, 11 metals, nutrients, biochemical oxygen demand (BOD), total solids (TS), total volatile solids (TVS), total suspended solids (TSS), total dissolved solids (TDS), turbidity, total organic carbon (TOC), pH, alkalinity, chemical oxygen demand (COD), hardness, nitrate, ammonia, phosphate, sulfide, sulfate, cyanide, chloride, and coliform bacteria." Piechota et al. (2004) reported the petroleum-based products were the found to be the most toxic followed by acrylic polymers and ligninsulfonate. Magnesium chloride was found to have the least toxicity but still higher than the control plots. This study also found dust suppressants reduced total suspended solids in runoff (Singh et al. 2003).

Irwin et al. (2008) identified the need to fill the information gap regarding dust suppressants and environmental impacts. The researches simulated rainfall on plots treated with six dust suppressant products and analyzed them for water quality and aquatic toxicity. Water quality parameters included pH, total dissolved solids, electrical conductivity, dissolved oxygen, total organic carbon, total suspended solids, nitrate, nitrite, and phosphate. The six dust suppressant products tested were surfactants, a synthetic organic, and synthetic polymer. The goal was to mimic desert climatic conditions at construction sites. Most water quality parameters tested were similar to the control plots. The most concerning result was the higher total suspended solids from the synthetic organic and polymer as compared to water alone. This was attributed to the particles binding together to form medium clumps but not stabilizing enough to prevent them from being mobilized by runoff. The researches stated that this probably could be alleviated by standard best management practices.

Shi et al. (2009) evaluated sodium chloride and magnesium chloride deicers on water quality. Three locations were sampled near road treated with deicers. The water quality parameters tested included pH, turbidity, dissolved oxygen, biological oxygen demand, chemical oxygen demand, chloride, total Kjeldahl nitrogen, and orthophosphate. Four storm events were sampled during the study and one set of samples captured pre, during, and post storm conditions. In regards of the relevant water quality parameters, the samples tested below the thresholds established by the United States Environmental Protection Agency (USEPA) with the exception of one. A single sample tested 250 mg/L for chloride concentration which matched the USEPA threshold. The site where the researchers were able to collect data for the pre, during, and post storm showed no increase in chloride.

Air Quality

Expectantly, most of the research on dust suppressants focuses on their effectiveness on preventing wind erosion. Although most water quality concerns are focused on the leaching and migration of the products into the water column, the effectiveness of these products on dust is also important to water quality. As mentioned earlier, once fines leave the surface of the road, the remaining material becomes unstable and more prone to mobilizing into storm water (Sanders et al. 1994). Lones and Coree (2002) reported that an untreated road can lose up 300 tons of aggregate per mile per year.

Edvardsson (2010) tested several dust suppressants including magnesium chloride solution, a calcium chloride solution, magnesium chloride flakes, calcium chloride flakes, calcium lignosulphonate, bitumen emulsion, rape oil, starch, and polysaccharide. The research was both field-based and lab tested. Tests were conducted at four sites where roads were divided into 13-16 different 1 km sections. This study was thorough with statistical calculations based on 40,000 sample values from 22 different observations points. As measured qualitatively and quantitatively, the chloride applications were the most effective. The analysis showed that the chloride solutions were more effective than the chloride solids regarding effective dust suppressants. This is likely due to the uniform application achieved with the solution. The lignosulphonate and bitumen emulsion treatments formed a brittle crust that was broken by vehicular traffic and reduced dust suppressant effectiveness. As compared to lignosulphonate, the chlorides persisted on the road surface and therefore remained effective longer. Edvardsson (2010) also measured toxicity and growth inhibition of the chlorides and found that chlorides applied at "…conventionally used… rates, does not constitute a threat to the environment." Lastly, the starch extracted from corn proved to be comparably effective to the other suppressants and the author suggests further research is justified.

Surdahl et al. (2005) tested seven different dust suppressants including a synthetic polymer emulsion, two electrochemical enzymes, an organic non-petroleum (lignosulfonate), a salt (magnesium chloride), and two organic non-petroleum's with salt additives. Each product was applied to a minimum one mile of unpaved road surface. The products evaluations were based on a visual inspection for dust control, washboarding, raveling, potholing, rutting, and leaching. The products were also evaluated based on field measurements of Dynamic Cone Penetrometer, Silt Load, Nuclear Density Gauge, and GeoGage Soil Stiffness tests. The researches emphasize throughout the document that all of the products were effective and acceptable. The overall score was highest for two organic non-petroleum plus salt products (vegetable corn oil + magnesium chloride and lignosulfonate plus magnesium). Magnesium and lignosulfonate were third and forth, respectively. The researcher emphasized that a lower score of the electrochemical enzymes could be a result of the soil characteristics of this particular site and these products may be more effective at sites with higher clay content.

Sanders et al. (1994) studied the effectiveness of lignin and chloride based products at reducing fugitive dust. They measured both the dust created and aggregate lost using several different treatments. The total aggregate losses from the treated section were 42-61 percent less than control plots and achieved 50-70 percent dust reduction. The data suggests that the lignosulfonate test section produced less dust than the chloride treatments. However, the authors reported anecdotally that the lignosulfonate was producing equal or more dust than the chloride sections soon after the research concluded. As for aggregate loss, magnesium chloride and lignosulfonate each lost the same amount of aggregate (1.0 tons/mile/year/vehicle) which was the least of the treatments tested. Calcium chloride lost 1.5 tons and the control lost 2.6 tons.

Grau (1992) evaluated the effectiveness of polyvinyl acetate liquid emulsion, magnesium chloride, and calcium chloride. The author reported these materials were tested at several military bases. Summarizing the benefits of each, Grau (1992) concluded the chloride brine solutions performed best on sand and gravel soils in areas that have average relative humidity of 30 percent. The chloride products were more effective on areas with wheel traffic when compared to the polyvinyl acetate. In at least one test plot, the surface film of polyvinyl acetate tore and was irreparable.

Gillies et al. (1999) tested the effectiveness for PM10 reduction of four dust suppressants: biocatalyst stabilizer, polymer emulsion, petroleum emulsion with polymer, and nonhazardous crude-oil-containing materials. The polymer emulsion showed 80 percent efficiency after a 12 month period. The nonhazardous crude-oil-containing material was 95 percent effective after an 8 month period. The petroleum emulsion with polymer was 73 percent effective after 3 month but only 49 percent after 12 months. The biocatalyst stabilizer was the poorest performer with only 33 percent in the first few months and deteriorating quickly thereafter.

Conclusion

Fugitive dust is a world, national, and local issue. The negative consequences are many including impacts to human health, the environment, and the economy. With over 1,700,000 miles of unpaved road in the U.S., permanent stabilization measures, e.g. paving, are often cost prohibitive. More economical dust suppressants measures exist and are used on over 400,000 miles of unpaved roads in the U.S. (Piechota et al., 2004). However, these products vary in their effectiveness and their potential environmental consequences have not always been evaluated rigorously (Piechota et al., 2004).

When selecting a dust suppressant for the Park, the product needs to be effective at preventing wind erosion while not adversely affecting storm water quality. Many of the studies reviewed suggested that products effectiveness will be influenced by the site conditions, especially soil characteristics. Observations reported at the Park since employing annual applications of magnesium chloride on the road surface suggest that this product is effective at preventing mobilization of fines and keeping the road surface stable (J. Mynk, personal communication, May 25th, 2012). These findings are supported by several studies which concluded that magnesium chloride is an effective road stabilizer (Grau, 1992; Evardsson, 2010; Sanders et al., 1994; Surdahl et al., 2005). Chlorides are estimated to make up 75-80 percent of the total dust suppressant used in the U.S. (Piechota et al., 2004) which is also an indication of their effectiveness.

During this literature search, magnesium chloride was not demonstrated to have an adverse effect on the storm water quality (Edvardsson, 2010; Goodrich et al., 2009; Shi et al., 2009) with the exception of a single sample (Shi et al., 2009). Relative to other products, Piechota et al. (2004) reported that magnesium chloride was the least toxic when compared to control plots. Although this product is likely to mobilize into the environment (Sanders and Addo, 1993), the concentrations have been below levels considered adverse to aquatic organisms (Edvardsson, 2010; Goodrich et al., 2009).

There are several alternatives to magnesium chloride but few have been studied carefully for both effectiveness and environmental effects (Bolander & Yamada, 1999; Piechota et al., 2004). Lignin products are the exception. The main concern for these products regarding water quality is the effect on the dissolved oxygen levels since they are derived from wood (CWPA, 2006; Bolander & Yamada, 1999). Piechota et al. (2004) summarized known studies and the effects of lignins on aquatic organisms and reported "high levels…in water bodies have high coloring effects, increase bio-chemical oxygen demand, reduce biological activity, and retard fish growth." Piechota et al. (2004) also reported that simulated run-off showed lignosulphonate was more toxic than magnesium chloride. While studies have found lignin products to be effective dust suppressants (Sanders and Addo, 1993; Sanders et al., 1994), few studies indicate chlorides are more effective in the long-term (Evardsson, 2010; Sanders & Addo, 1993). Lignin products may be incompatible with park operations for several other reasons. First, since the product needs to be mixed in placed (Bolander & Yamada, 1999), cultural resources below the road may be impacted. Second, the product is slippery when wet (WTIC, 1997) and brittle when dry (Edvardsson, 2010; WTIC, 1997). A slippery surface would be undesirable for staff and visitors and the dry climate may result in the brittle surface chipping and mobilizing. Third, this product may discolor vehicle paint.

Calcium chloride has also been the focus of research and many of the advantages and disadvantages are similar to magnesium chloride. However, since it does not perform as well in drier climates and is highly corrosive to aluminum (Bolander & Yamada, 1999) the Park does not view this as a sensible alternative.

Moving forward, the Park plans to continue to utilize magnesium chloride solution for dust control on the park road. Below is an outline of BMPs the Park will officially adopt when performing the application.

- Repair unstable road surfaces prior to magnesium chloride application.
- Do not apply magnesium chloride during storm events.
- Restrict the use of magnesium chloride within 25 feet of Corral Hollow Creek.
- Adhere to manufactures minimum and maximum application rate.
- If road surface is dry, dampen.
- Monitor chloride levels during the Metals Assessment (SWMP April 2012, *in press*)

While many dust suppressants are used to stabilize unpaved road surface, many have not been rigorously evaluated for potential environmental impacts. Considering the consequences that result from untreated unpaved road surfaces, it is clear that dust suppressants can play a major role in improving the environment. For the Park, the most sensible option is magnesium chloride since it has proven to be effective generally and on-site and research has shown minimal environmental impacts to surface water resources.

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