Dust Control Products at Hagerman National Wildlife Refuge, Texas

Environmental Safety and Performance

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Controlling fugitive dust while protecting natural resources is a challenge faced by all managers of unpaved roads. Unfortunately, road managers choosing between dust control products often have little objective environmental information to aid their decisions. To address this information gap, the U.S. Geological Survey and the U.S. Fish and Wildlife Service collaborated on a field test of three dust control products with the objectives of (*a*) evaluating product performance under real-world conditions, (*b*) verifying the environmental safety of products identified as practically nontoxic in laboratory tests, and (*c*) testing the feasibility of several environmental monitoring techniques for use in dust control tests. In cooperation with refuge staff and product vendors, three products (one magnesium chloride plus binder, one cellulose, and one synthetic fluid plus binder) were applied in July 2012 to replicated road sections at the Hagerman National Wildlife Refuge in Texas. These sections were monitored periodically for 12 months after application. Product performance was assessed by mobile-mounted particulate-matter meters measuring production of fugitive dust and by observations of road conditions. Environmental safety was evaluated through on-site biological observations and leaching tests with samples of treated aggregate. All products reduced dust and improved surface condition during those 12 months. Planned environmental measurements were not always compatible with day-to-day refuge management actions; this incompatibility highlighted the need for flexible biological monitoring plans. As one of the first field tests of dust suppressants that explicitly incorporated biological endpoints, this effort provides valuable information for improving field tests and for developing laboratory or semifield alternatives.

One of the primary challenges associated with maintaining a network of unpaved roads is controlling fugitive dust. Dust can create driving hazards by impairing visibility and be a health hazard and nuisance for residents living near roads. In addition, loss of fine material from the road surface degrades ride quality and increases road maintenance costs. Unfortunately, road managers seeking to control dust with chemical products have few sources of objective information with which to evaluate product efficacy and environmental safety. Dust control decisions, therefore, are often based on claims by product vendors or on a series of trial-and-error field tests.

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The need for scientifically defensible information to guide dust control and unpaved road stabilization is widely recognized. Standardized field studies, such as those performed by the Central Federal Lands Highway Division at Seedskadee (*1*) and Buenos Aires (*2*) National Wildlife Refuges (NWRs), have advanced the understanding of product performance under different weather and soil conditions but were not able to include formal biological monitoring to ensure that product applications were environmentally benign. This lack of reliable data on potential environmental effects is problematic for all road managers seeking environmentally responsible dust control and road stabilization but particularly for natural resource management agencies such as the U.S. Fish and Wildlife Service (USFWS).

Determining potential environmental impacts of dust control products is difficult because of the wide variety of product compositions and application methods. More than 190 products are commercially available for use as dust suppressants and soil stabilizers (D. Jones, University of California, Davis, personal communication), including water-absorbing compounds (e.g., calcium chloride and magnesium chloride), organic petroleum products (e.g., cutback solvents and asphalt emulsions), nonpetroleum organics (e.g., lignin sulfonates, tall oil emulsions, and vegetable oils), synthetic polymers (e.g., vinyl acrylic and vinyl acetate compounds), and electrochemical products (e.g., enzyme blends and sulfonated oils). The composition of these products is often proprietary or poorly documented on safety data sheets. In addition, dilution rates and application rates and methods all influence the likelihood of product entry into roadside habitats and the subsequent exposure of roadside plant and animal communities. For accurate assessment of environmental effects of product application, tests should address potential product toxicity under typical use conditions.

The field test described here is part of the third and final phase of a comprehensive project by the U.S. Geological Survey (USGS) and USFWS. Phases 1 and 2 identified nontoxic dust control products through a screening effort with rainbow trout (*Oncorhynchus mykiss*) and subsequently tested those products with additional vertebrate, invertebrate, and plant species to confirm lack of adverse effects (USGS, unpublished data). In the Phase 3 field test, three products selected from among those tested in the laboratory were applied to roads at Hagerman NWR in Texas. The specific objectives for the field test were to (*a*) evaluate product performance for 12 months, through fugitive dust monitoring and road condition assessments, (*b*) verify the environmental safety of products identified as practically nontoxic in previous laboratory tests, and (*c*) test the feasibility of different field environmental monitoring techniques and semifield environmental tests for use in future dust control tests.

METHODS

Site Description

The Hagerman NWR covers almost 5,000 hectares of upland, wetland, crop land, and open water adjacent to Lake Texoma in northern Texas. The refuge receives approximately 175,000 visitors per year. Two primary aggregate-surfaced roads service the refuge: Wildlife Drive, which forms the majority of an auto-tour loop along the lake, and Bennett Lane, which crosses the refuge from the southeast to the northwest. Wildlife Drive receives primarily traffic from passenger vehicles, while Bennett Lane receives both passenger traffic and heavy truck and equipment traffic associated with more than 150 active oil and gas wells on the refuge (Figure 1). Monthly vehicle counts on Wildlife Drive ranged from 3,200 to 5,300 in 2010–2011 (Hagerman NWR, unpublished data). Both roads were rehabilitated in 2009 by the FHWA by using aggregate of ⅝-in. maximum size sourced from North Texas Crushed Stone, Gainesville.

Application Procedure and Project Timeline

Three products were selected for application in the Hagerman field trials: Durablend, a magnesium chloride with polymeric binder (EnviroTech Services, Inc., Greeley, Colorado); Dust Stop, a modified cellulose blend powder (Cypher Environmental, Winnipeg, Manitoba, Canada); and EnviroKleen, a synthetic fluid plus binder (Midwest Industrial Supply, Inc., Canton, Ohio). These test products were selected from among products that met the following criteria: (*a*) classified as practically nontoxic according to U.S. Environmental Protection Agency (EPA) ecotoxicity categories on the basis of previous USGS laboratory toxicity tests with multiple organisms; (*b*) showed compatibility with the road surface aggregate, climate, and traffic volumes at Hagerman NWR as determined by product vendors; (*c*) supplied by a vendor willing to participate in the field trials; and (*d*) approved by refuge management for use in the trial. Of the eligible products, the three finalists were selected to represent a variety of formulations and product vendors.

Each product was applied to one section of Wildlife Drive and one section of Bennett Lane. An untreated reference section was also created for each road. Test section layout and respective lengths are shown in Figure 1. Before application of the products, each road was shaped and maintenance-bladed by refuge personnel with a Caterpillar 12G motor grader. Reference sections received no treatment other than this shaping and maintenance-blading. The application procedure for each product on treated sections was designed and supervised by respective vendors. Therefore, product application procedures were not identical but matched the vendors' recommended methods as closely as possible. Products were applied from July 9 to 13, 2012. At least one vendor representative was on site during the application of each product.

Durablend was transported to the refuge in two tanker trucks (51,100 L). For Durablend application, the road was watered and then cut to a depth of 5 to 8 cm. The mix-in product was applied in two passes (1.67 L/m^2 each) by an EnviroTech spray truck, with blade-mixing after each application. The road was then shaped, compacted with a 10-ton rubber-tire roller, and rewet with a water truck before a final topical application of 1.13 L/m^2 of Durablend.

Dust Stop was shipped to the refuge as a pallet of 11.34-kg bags (1,134 kg total). Dust Stop was applied in two phases: initial mix-in and topical applications with a water truck and a topical application with a hydroseeder 2 weeks later. Initial applications were planned at 0.45 kg/5.1 m^2 applied as multiple passes with a dilute solution of Dust Stop mixed into the top 5 cm of road surface, followed

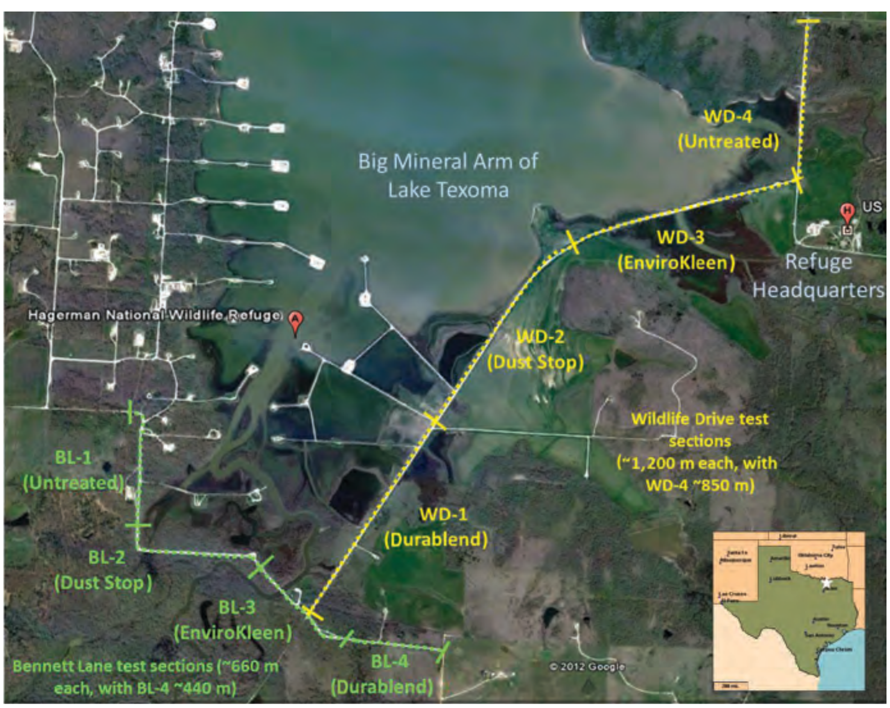

FIGURE 1 Test section layout and lengths at Hagerman NWR (WD = Wildlife Drive; BL = Bennett Lane).

by a more concentrated topical application. The appropriate weight of Dust Stop powder was mixed with Dust Stop water conditioner (0.9 kg/3,785 L of water) and water in the water truck by using an eductor unit, or directly in the hydroseeder by using internal mixing blades. In both applications, incompatibility between the equipment and the viscosity of the product prevented the application of the full designed application rate. The final application rate of Dust Stop was approximately 70% of the target rate on Wildlife Drive and 40% of the target rate on Bennett Lane.

EnviroKleen was transported to the refuge in a Midwest Industrial Supply spray truck with pup trailer (17,035 L total). The road sections treated with EnviroKleen were cut 5 cm, shaped with the grader, compacted with a steel-drum roller, and then given a topical application of 1.36 L/m^2 applied by the Midwest Industrial Supply spray truck in multiple passes. The following day, the EnviroKleen sections received a final compaction with a steel-drum roller.

Decisions regarding additional maintenance applications were made by each vendor. Approximately 2½ months after the original applications, EnviroKleen-treated sections received a maintenance treatment at 0.68 L/m^2 (half the original application rate). Sections treated with Durablend and Dust Stop received only the original applications.

Product performance and environmental safety were monitored for 1 year after the initial product applications. Monitoring periods occurred at 2 weeks and 1, 2, 4, and 12 months after application. All monitoring was conducted by USGS personnel with assistance from refuge staff.

Performance Monitoring

Dust production, road surface condition, and frequency of required maintenance were included in the performance evaluation of the dust suppressant products at Hagerman NWR. Dust production and surface condition represented the most common concerns of drivers on the refuge. A reduction in required maintenance over the course of the 12-month monitoring period was a goal of refuge staff and was also used as an indication of overall project success.

Dust Production

Dust production on each treated and untreated road section was measured with a DustTrak DRX aerosol monitor (TSI Inc., Shoreview, Minnesota), which uses a laser photometer to measure particulate matter in several size ranges simultaneously, from particulate matter 0.02 to 1.0 μ/m diameter (PM_1) to total particulate matter. The DustTrak DRX was mounted on the tailgate of a refuge truck with the intake tube secured horizontally 1 m above the road surface, which is the height at which peak PM_{10} (≤10 μ/m in diameter) exposure is expected (*3*). On each sampling date, each road section was driven three times with a DustTrak sampling rate of 1 sample per second to yield three replicate dust profiles per section. All measurements were taken with the DustTrak mounted on the same refuge truck, with the same driver for all measurements on a sampling date. On each section, the driver smoothly accelerated to 40 km/h in accordance with the recommendations of Edvardsson and Magnusson (*4*) and Thenoux et al. (*5*) and maintained that speed until smoothly decelerating to a stop at the boundary between treatment sections. Any passing cars or other influences were recorded for each sampling run.

The raw data files from each run were then processed to ensure that measurements were as comparable as possible across all treated and untreated sections. To eliminate influence from adjacent treated or untreated sections, both the beginning and end of each run were truncated by visually examining the raw data and preserving a set number of data points, beginning from 5 s after total particulate matter measurements diverged from baseline. These preserved data were further edited to eliminate out-of-range points caused by passing cars noted at the time of measurements, or in two cases, by sharp curves at the end of test sections. Final preserved data sets for each run (70 s for Wildlife Drive sections and 40 s for Bennett Lane sections) should therefore be representative of dust production on each section, independent of the influence of adjacent sections or differences in road geometry. The three replicate sets of preserved data for each section were then averaged to create a composite second-by-second profile of dust generation for each section on each sampling date.

Surface Condition

Surface condition was assessed by using a formal objective rating procedure on November 9, 2012, as well as informal observations at each sampling period. The objective rating procedure was based on that used in product evaluations by the Central Federal Lands Highway Division at the Seedskadee NWR project (*1*). Each section was driven with four stops. At each stop, three independent observers measured and rated the number and depth of potholes, rutting, raveling, and washboarding. When individual observers differed on ratings, the group came to a consensus before continuing. Originally, the objective rating system also included dust production observed while driving the section, but these ratings were removed because dust production had been characterized more thoroughly with the DustTrak DRX meter measurements. The scores for each surface distress were combined and normalized to provide a basis of comparison for surface condition on treated and untreated sections of each road. At the time of the assessment of surface conditions, the untreated section of Wildlife Drive had recently been regraded because of surface distresses and therefore was not included in the assessment.

Frequency of Required Maintenance

Frequency of required maintenance on the test roads was assessed through conversations with refuge staff, who were not prohibited from performing routine maintenance as needed but were asked to record the date, type, and cause of any maintenance activities when they occurred.

ENVIRONMENTAL SAFETY

The products selected for use at Hagerman NWR were among the least toxic in previous laboratory toxicity tests, and field tests were designed to confirm the lack of adverse environmental impacts when applied in the field under typical application conditions. On the basis of previous work on environmental pathways (*6, 7*), environmental effects were possible through at least four routes: (*a*) product runoff or leaching with precipitation, (*b*) potential modification of soil chemistry adjacent to treated sections, (*c*) direct overspray of product during application, or (*d*) effects on vegetation through the movement of treated particulate matter. These four types of potential environmental effects were addressed through a combination of field and field–laboratory approaches.

Aggregate Leaching Tests

Ideally, runoff or leachate from precipitation could be collected from each treated section in the field and assessed for potential impacts on aquatic organisms or water quality. This approach has been used successfully on experimental plots with simulated rainfall [e.g., Piechota et al. (*7*), Irwin et al. (*8*)]. However, because the installation of collection systems would have caused unacceptable disturbance to roadside habitats at Hagerman NWR, samples of aggregate were collected from each treated and untreated section on Wildlife Drive over time and transported to the laboratory for controlled leaching tests. Aggregate was collected at three points during the project: immediately after, 4 months after, and 1 year after application. Composite aggregate samples (20 kg each) were created by collecting material from the top 5 cm of road surface at three locations adjacent to the wheelpath in each road section. Sampling points were separated by 10 m and were located near the center of each section. Samples were stored in a climate-controlled room at the Columbia Environmental Research Center in Columbia, Missouri, until the leaching tests. Each sample was homogenized, and a 1-kg subsample was taken. This subsample was air dried for 72 h and then placed in a closed plastic tub with a disposable desiccator plate overnight to complete the drying process.

To create leachates, 600 g of each dried aggregate were added to 12 L of deionized water at a 20:1 (liquid:solid) ratio. Aggregate samples were left to soak undisturbed for 48 h, and the overlying water was then siphoned off into 10-L carboys. This liquid:solid ratio is the same as used in the U.S. EPA's Synthetic Precipitation Leaching Procedure (Test Method SW846), but other conditions were modified from that procedure to increase the relevance of leaching tests to field conditions. Most notably, the current leaching tests used deionized water as the extraction fluid instead of simulated acid rain, did not use additional crushing of the aggregate to reduce particle size, and used a static soak to simulate inundation of the road by flooding rather than agitating the sample and extraction fluid. The goals of leachate creation were to assess potential toxicity to a representative aquatic organism and to characterize potential impacts on basic water quality parameters.

Leachates were used in 96-h acute toxicity tests with juvenile rainbow trout, in basic accordance with ASTM E729-96 (*9*). Each leachate was used to fill three 3-L replicate treatment jars. Leachates from treated aggregate were compared with those from both untreated aggregate and controls. Control jars were filled with well water diluted with deionized water to a hardness of ~100 mg/L as calcium carbonate ($CaCO_3$). Before the tests, juvenile rainbow trout were acclimated to the test temperature of 12°C and water hardness of 100 mg/L as $CaCO_3$ for at least 48 h. Five juvenile rainbow trout (32 days post-swim-up) were stocked in each treatment or control jar. Any mortality or abnormality of test fish was recorded daily.

Water quality characteristics (dissolved oxygen, conductivity, pH, alkalinity, hardness, and ammonia content) were measured on Days 0 and 4 of the tests, with additional checks of dissolved oxygen and temperature on Day 2.

Soil Chemistry Samples

To assess the potential effects of the transport of treated road dust on roadside soil chemistry, soil samples were taken along three parallel transects adjacent to each treated section of Wildlife Drive 1 year after initial product applications. Transects ran north from the edge of the road because prevailing winds are from the south for much of the year at Hagerman NWR, and this orientation was assumed to represent maximum potential deposition of road dust on roadside habitats. Soil samples were not taken adjacent to the untreated section because the road itself was aligned with prevailing winds (north–south). Replicate transects for a particular road section were separated from one another by approximately 10 m and had sampling stations at 5, 10, 20, and 40 m from the road's edge. At each sampling station, a 1-m^2 plot was cleared of vegetation, and soil was taken from the four corners and the center of the plot to a depth of 2 in. Composite samples were placed in plastic zip-top bags, allowed to air dry in the laboratory, and then sent for soil analysis by the Texas A&M Soil, Water and Forage Testing Laboratory (College Station).

Other Environmental Observations

Additional observations were made during the initial applications. These included watching for direct product overspray or drift during applications, direct runoff of product from the treated surface, and any unintended discharge or spill of product. To evaluate potential effects of product application on roadside vegetative communities, two vegetation sampling transects were established adjacent to each treated and untreated section on Wildlife Drive. Unfortunately, maintaining these transects was not compatible with normal refuge management activities, namely roadside mowing and plowing for winter wheat. Therefore, at each monitoring period, qualitative vegetation observations were made.

RESULTS AND DISCUSSION

Performance Monitoring

Dust Production

Absolute dust production varied greatly over the year-long monitoring period. On Wildlife Drive, dust production was greatest at the August and November 2012 sampling periods, with total particulate matter measurements up to 20 times as great as those on other dates (Figure 2). This variability was not surprising given the sporadic nature of rainfall at the refuge. The August sampling period followed 17 days with negligible precipitation and temperatures around 35°C. Likewise, the 24 days before the November sampling period had no appreciable precipitation.

Bennett Lane showed similar patterns of dust production, with total particulate matter concentrations up to 50 mg/m^3 at the August 2012 sampling date (Figure 3). Interestingly, Bennett Lane did not show consistently higher dust production than Wildlife Drive over time despite increased use by heavy oil and gas trucks. This pattern may have been the result of differences in roadside habitat. Wildlife Drive crosses wide areas of open habitat with few trees. Bennett Lane, in contrast, is primarily wooded, so its trees likely provide a shield from the drying effects of both wind and sun. Alternatively, the heavy traffic may have increased compaction on the Bennett Lane section, particularly after rainfall.

Despite variability among sampling periods, the overall pattern of response among sections appeared fairly consistent. In order of best performance as measured by suppression of dust, the sections of Wildlife Drive would be ranked as follows: Durablend first,

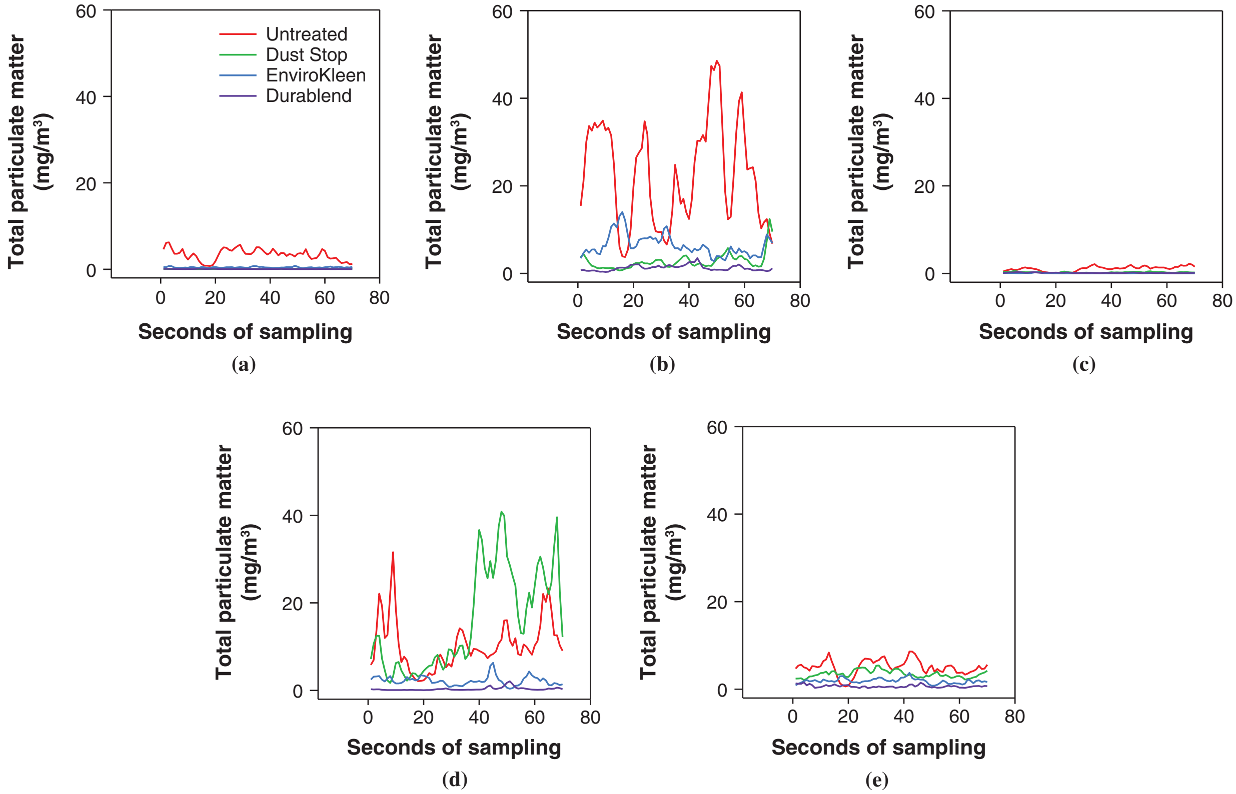

FIGURE 2 Composite dust profiles for five sampling dates for each section of Wildlife Drive, as measured by DustTrak DRX meter: (*a*) July 27, 2012; (*b*) August 14, 2012; (*c*) September 18, 2012; (*d*) November 8, 2012; and (*e*) July 23, 2013. (All *y*-axes set at same maximum value for comparison.)

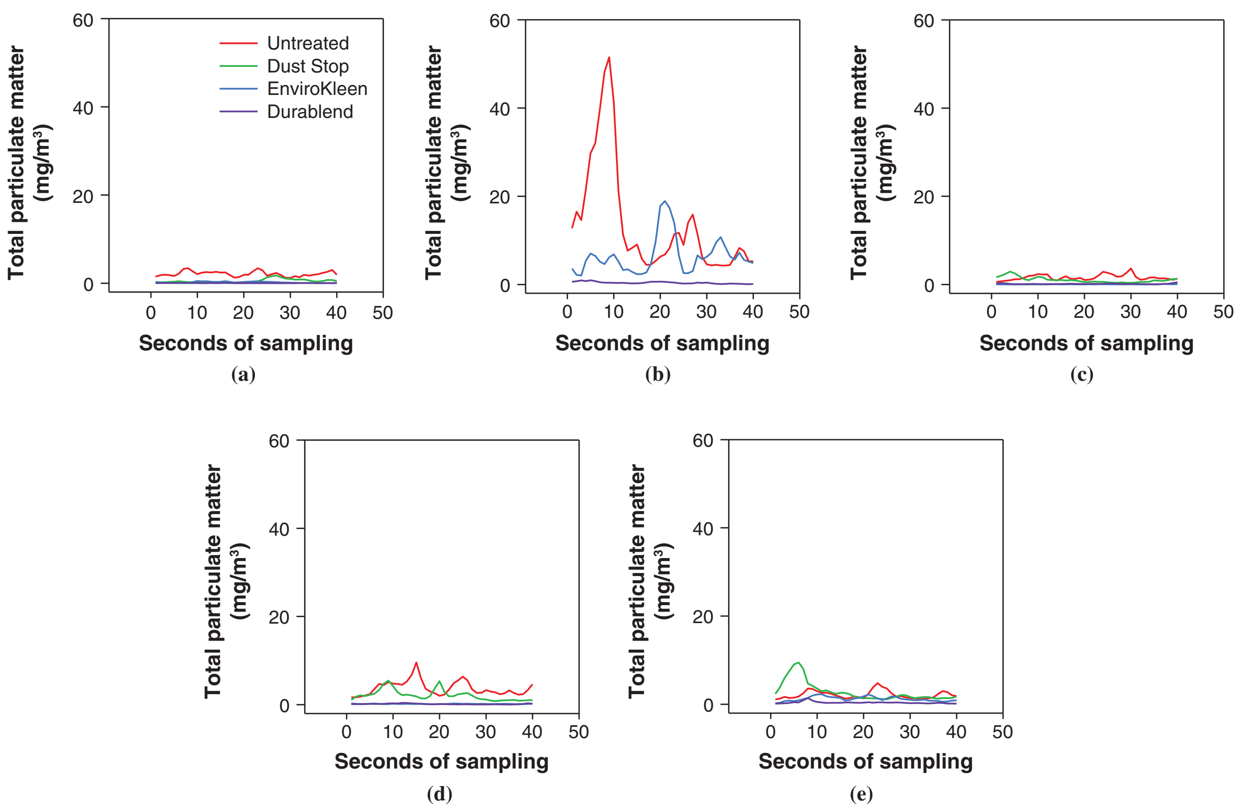

FIGURE 3 Composite dust profiles for five sampling dates for each section of Bennett Lane, as measured by DustTrak DRX meter: (*a*) July 27, 2012; (*b*) August 14, 2012; (*c*) September 18, 2012; (*d*) November 8, 2012; and (*e*) July 23, 2013. [All *y*-axes set at same maximum value for comparison. Dust Stop excluded from August 14 graph because low application rate (40% of target) resulted in abnormally high dust production on this date.]

EnviroKleen second, Dust Stop third, and untreated last. Each of the products reduced dust by as much as 95% relative to the untreated section. Bennett Lane showed a similar pattern of response, with a performance ranking of Durablend followed by EnviroKleen and then by untreated. Because of the low (less than 50% of target) application rate for Dust Stop on Bennett Lane, Dust Stop was not included in product comparisons for Bennett Lane. On both roads, the difference between treated and untreated sections was much more pronounced when conditions were extremely dry.

Because dust measurements on a particular sampling date offer only a snapshot of product performance, sampling dates must either be (*a*) carefully chosen based on conditions of interest or (*b*) sufficiently numerous to capture a range of conditions. In the current study, sampling dates were set in advance and covered both low and high dust conditions. Therefore, dust data are assumed to be representative of a product's performance over the entire monitoring year.

Surface Condition

Surface condition ratings conducted 4 months after the initial applications indicated that all three products improved surface condition on Wildlife Drive and Bennett Lane relative to untreated sections (Table 1). These objective ratings were consistent with qualitative observations of the surfaces made at each monitoring date. Surface condition ratings and dust suppression performance for a given product were not always tightly correlated, however. For example, while Durablend-treated sections consistently produced the least dust on both Wildlife Drive and Bennett Lane, these sections were ranked somewhat lower than the other two products on surface condition, primarily as a result of rutting. Dust Stop, however, was ranked more highly in surface condition assessments than in dust suppression.

Frequency of Required Maintenance

On the basis of conversations with refuge staff, maintenance was triggered when potholes or rutting was sufficiently pronounced to affect the ride quality negatively for refuge visitors. On the basis of this criterion, Wildlife Drive and Bennett Lane required maintenance in the form of light blading at the end of August 2012 and the end of April 2013 in preparation for major events at the refuge. The untreated section of Wildlife Drive required extra blading in early November 2012. In addition, both roads were watered, bladed, and recompacted in late November 2012 to remove surface distresses in preparation for the refuge's heaviest traffic season (November to March). Although traffic conditions during the 12-month monitoring period were considered typical for Wildlife Drive, Bennett Lane experienced an especially intense pulse of heavy traffic associated with the development of a new oil and gas well at the northwest corner of the refuge. Because of the road damage caused by this traffic, Bennett Lane required spot treatments of additional aggregate, blading, and shaping in June 2013.

In a typical year before product applications, Wildlife Drive and Bennett Lane would require blading every month. This frequency could be even greater, particularly during the busy season of November to March. Therefore, product application in this case reduced the frequency of required maintenance from more than 12 to three or four times per year on the treated roads and was considered a success. Frequencies of maintenance between treated and untreated sections or among treated sections were not compared because the refuge's engineering equipment operator preferred to blade each road as a unit rather than in sections.

Environmental Safety

Aggregate Leaching Tests

Survival of juvenile rainbow trout exposed to leachates from Hagerman NWR aggregate samples was 100% across all products and all periods. Survival when exposed to leachate from untreated aggregate or control water was also 100% (Table 2). No physiological or behavioral abnormalities were observed in any fish in any treatment. Dissolved oxygen, pH, and ammonia content remained within suitable levels for the duration of the test. The most pronounced differences in leachate water quality among the different products were

TABLE 1 Objective Road Surface Condition Evaluation

Treatment Section	Washboarding[a]	Raveling[a]	Rutting[a]	Potholing[a]	Normalized Score[a]	Ranking[b]
Wildlife Drive						
Durablend	9.3	8.3	6.7	8.0	80.8	3
EnviroKleen	9.7	8.3	8.3	9.3	89.0	2
Dust Stop	10.0	8.3	9.3	8.3	89.8	1
Untreated	—	—	—	—	—	4
Bennett Lane						
Durablend	10.0	8.3	7.0	7.7	82.5	3
EnviroKleen	10.0	8.3	9.0	9.3	91.5	1
Dust Stop[c]	9.7	9.0	8.0	8.7	88.5	2
Untreated	8.7	7.3	7.7	8.3	80.0	4

NOTE: — = recently regraded and therefore not assessed. Because regrading was in response to surface distresses, the untreated section was assigned the lowest ranking of the four sections on Wildlife Drive.
[a]Higher scores indicate better performance.
[b]Products ranked 1 to 4 (high to low) on basis of normalized score.
[c]Actual application rate was approximately 40% of target rate.

TABLE 2 Leachate Test Results

Aggregate Sample Timing	Rainbow Trout Survival	Dissolved Oxygen (mg/L)	Conductivity (μS/cm)	pH	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Ammonia (mg/L as N)
Durablend							
At application	100%	8.05 (0.22)	1,797 (10)	7.47 (0.42)	27 (7)	736 (62)	0.15 (0.17)
4 months	100%	8.28 (0.28)	1,458 (0)	7.43 (0.45)	26 (3)	624 (34)	0.19 (0.16)
12 months	100%	8.38 (0.24)	232 (9)	7.59 (0.71)	20 (0)	90 (3)	0.17 (0.20)
Dust Stop							
At application	100%	8.20 (0.51)	113 (27)	7.62 (0.47)	30 (3)	44 (6)	0.26 (0.27)
4 months	100%	8.16 (0.14)	201 (13)	7.66 (0.57)	27 (1)	76 (8)	0.29 (0.36)
12 months	100%	8.27 (0.15)	236 (49)	7.67 (0.55)	26 (3)	98 (17)	0.38 (0.44)
EnviroKleen							
At application	100%	8.42 (0.20)	110 (6)	7.79 (0.68)	29 (4)	43 (7)	0.27 (0.35)
4 months	100%	8.05 (0.30)	203 (28)	7.61 (0.49)	28 (3)	71 (16)	0.22 (0.19)
12 months	100%	8.24 (0.23)	238 (27)	7.64 (0.55)	27 (4)	95 (10)	0.21 (0.26)
Untreated							
At application	100%	8.54 (0.19)	146 (10)	7.64 (0.74)	24 (3)	59 (1)	0.15 (0.14)
4 months	100%	7.98 (0.21)	129 (20)	7.83 (0.78)	33 (1)	53 (1)	0.18 (0.13)
12 months	100%	8.22 (0.24)	139 (14)	7.76 (0.83)	26 (3)	60 (0)	0.15 (0.16)
Control Water							
na	100%	8.24 (0.83)	262 (4)	7.96 (0.15)	97 (4)	106 (0)	0.18 (0.23)

NOTE: Dissolved oxygen was measured on Test Days 0, 2, and 4. All other parameters measured on Days 0 and 4. Values are means with standard deviation given in parentheses; na = not applicable.

dramatically higher conductivity (up to 1,797 μS/cm) and hardness (up to 736 mg/L as $CaCO_3$) in leachates from Durablend-treated aggregate, particularly from earlier in the monitoring period (Table 2). These differences would be expected because of the magnesium chloride–based formulation of Durablend.

This leachate test was designed to represent the potential effects of products on water quality under a worst-case inundation scenario (i.e., aggregate completely soaked for an extended period in a small volume of water). Under more realistic circumstances, any road inundation would be associated with much greater volumes of water, and inputs from treated aggregates would be correspondingly dilute. Similarly, the influence of products on precipitation runoff from treated sections would likely be more modest than the influence seen with aggregate soaking, given the more limited contact time between precipitation and the aggregate. This prediction is supported by Piechota et al., who observed that simulated runoff from a plot treated with a magnesium chloride product had a conductivity value of less than 400 μS/cm compared with the current study's maximum conductivity of 1,797 μS/cm from aggregate treated with Durablend, magnesium chloride plus binder (*7*). Therefore, any aquatic toxicity or change in water quality parameters seen with the modified leaching procedure described here should be an extremely conservative prediction of possible effects in the field.

Although the limited number of samples in the current study preclude any broad generalizations, these data suggest that a modified leaching procedure (e.g., deionized water as extraction fluid, no particle size reduction, and no agitation of extraction vessels) may be a useful method for estimating effects of treated aggregates on water quality and aquatic organisms when field collection of runoff or leachates is not possible.

Soil Chemistry Samples

Replicated soil samples taken 5, 10, 20, and 40 m from the road's edge on Wildlife Drive showed no clear influence of dust control products on soil conductivity, magnesium levels, pH, or calcium 12 months after application. Elevated conductivity or magnesium levels adjacent to the Durablend-treated section could have indicated movement of the magnesium chloride–based product from the roadway. In addition, no clear signal came from either soil pH or calcium level, each of which may be elevated in soils adjacent to roads surfaced with limestone aggregate as a result of transport and deposition of limestone dust (*10*). Although efforts were made to locate the sampling transects in the most consistent locations possible, variability in natural soil types on the refuge may have influenced the ability to detect soil chemistry differences associated with either product movement or dust deposition over time.

Other Environmental Observations

No product overspray onto roadside habitats was observed on any of the treated sections. In all cases, application was limited to the aggregate-surfaced portion of the roadway. Computerized spray systems provided by the Durablend and EnviroKleen vendors produced precise edges to the treated area that, in some cases, were still visible months later. The water truck and hydroseeder used for Dust Stop applications also had adequate precision to prevent introduction of product into roadside habitats. No direct runoff or product spills occurred.

Qualitative vegetation observations at each monitoring period recorded no adverse effects of product application on vegetation.

Roadside vegetation varied with season and consisted primarily of nonnative, disturbance-tolerant species. This vegetation pattern is common along roads, even in areas actively managed for natural resources [e.g., Tyser and Worley (*11*)]. Because of the spatial and temporal heterogeneity of vegetative communities, isolating of any effect of product application from other influences may be difficult. When the possible vegetation impacts of dust control products are considered, the best decision may be to determine whether any sensitive, threatened, or endangered species occurs in roadside communities and then to perform laboratory or greenhouse studies with the species of interest.

Although this study detected no negative environmental effects of product application during the 12-month monitoring period, the authors cannot draw conclusions about potential longer-term effects or effects associated with residual buildup of product from repeated applications. Future tests and any formal environmental testing protocol should address the common practice of repeated product applications.

CONCLUSIONS

- All three products tested reduced dust production, improved surface condition, and reduced the need for maintenance on roads at the Hagerman NWR relative to untreated sections. These improvements were apparent under both normal refuge traffic and heavy oil and gas traffic conditions, as represented by Wildlife Drive and Bennett Lane, respectively.
- No adverse environmental effects of application were observed for aquatic organisms exposed to leachates from treated aggregates in the laboratory or for vegetation adjacent to treated road sections in the field.
- Both dust production and surface condition should be considered in future evaluations of product performance because both are important indicators of treatment success.
- The mobile-mounted DustTrak DRX aerosol monitor provided practical, replicated measurements of particulate matter mass and size fraction of road dust for comparisons among sections.
- The semifield approaches (aggregate leaching tests) used in this project were a useful way to explore realistic environmental effects of dust suppressant application without disrupting normal refuge activities. These approaches could be used as a complement to a field trial, as in the current study, or in some cases may be a more reasonable alternative than a field trial. Coupled with verified laboratory performance tests that are currently being developed, these semifield environmental approaches could be used to predict environmental effects of interest.
- From this project and the work of others, a laboratory-based environmental testing protocol for dust control and soil stabilization products is being developed. The protocol will specify recommended toxicity tests and acceptable outcomes as well as recommended analytical tests with suggested threshold levels for chemical constituents. A draft form of this protocol is in review with several university, government, and industry representatives.
- Overall, this field test will support unpaved road managers in efforts to reduce dust and improve driver safety, while protecting fish, wildlife, and plant resources.

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