Preliminary Investigation (PI-0284)

Caltrans Division of Research, Innovation and System Information

Surface Applications of Fire Retardants

Requested by
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The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field. The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this publication are for clarity only.

Table of Contents

Executive Summary

Background

The U.S. Forest Service (USFS) and California Department of Forestry and Fire Protection (CAL FIRE) use fire retardants to reduce the intensity and spread of ongoing wildfires. The USFS uses fire retardants in consultation with other federal agencies such as U.S. Fish and Wildlife and the National Oceanic and Atmospheric Administration (NOAA)–Fisheries to balance the need to protect critical or sensitive resources with the need to effectively control wildfire emergencies.

Fire retardants are generally used during emergencies to extinguish ongoing active fires. These retardants are typically applied aerially outside the active fire zone to control the fire's spread. However, applying fire-retardant products from the ground before the onset of the fire season may be an effective preventive measure in fire management.

To determine whether to include pre-fire season application of these products in its vegetation management program, the California Department of Transportation (Caltrans) sought information about any existing use of ground-based fire retardants as a preventive measure on the roadside, including environmental and regulatory considerations of these products. CTC & Associates assisted Caltrans in this information-gathering effort by conducting an online survey of state departments of transportation (DOTs) about their knowledge of and experience using ground-based fire retardants as a preventive measure, including environmentally safe application practices and other best management practices. Fire management experts from the Missoula Technology and Development Center and CAL FIRE were also consulted for information about ground-applied wildfire chemical systems used along roadsides. In addition, a literature search of domestic in-progress and completed research was conducted to examine available resources related to the pre-fire season applications of ground-applied fire retardants along roadsides and other open corridors as a preventive measure.

Summary of Findings

Survey of Practice

An online survey of members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance sought information about the use of ground-applied fire retardants as a preventive measure to reduce the risk of wildfire. The national survey uncovered limited information. None of the 12 state transportation agencies responding to the survey use ground-applied fire retardants on the highway system as a preventive measure to reduce the risk of wildfire. Many of these states do not have a history of wildfires or do not experience a significant amount of wildfire activity (Alabama, Florida, Maine, Maryland, Michigan, Missouri, Tennessee and Vermont).

In Colorado, which is currently experiencing a significantly active wildfire season, these retardants could potentially help fire management but the state has not addressed operational factors related to the products. Both Colorado and Florida DOTs expressed concern about environmental and other impacts of fire retardants. The cost associated with the application of ground-based fire retardants is the primary reason Montana DOT has not used or considered using these products. Idaho Transportation Department uses alternative vegetation management practices, such as bare ground treatment near guardrails, and mowing and

herbicide applications to reduce vegetation, in fire-prone areas. Table ES1 summarizes survey responses.

Table ES1. Factors Affecting the Use of Ground-Applied Fire Retardants

Factor	State	Description
Infrequent Wildfire Activity	Alabama, Florida, Maine, Maryland, Michigan, Missouri, Tennessee, Vermont	• *Alabama*. Except during droughts, fire not an issue in rights of way. • *Michigan*. Sufficient rain and snow most years create "verdant roadside vegetation." • *Missouri*. Infrequent grass fires or forest fires. Controlled without additional design considerations or strategies. • *Tennessee*. Significant wildfires not an issue in rights of way. (Fires have occurred in the National Park Service areas of eastern Tennessee and in the Great Smoky Mountains National Park.)

Operational Issues and Impacts	Colorado, Florida, Kansas, Montana	• *Colorado:*
		  ○ Operational issues of ground-applied fire retardants not addressed.
		  ○ Insufficient information about the environmental impact of these retardants on roads.
		• *Florida.* Insufficient information about the potential impacts of fire retardants.
		• *Kansas*. Effect of fire retardants on grass fires unknown.
		• *Montana*. Cost of applying ground-based fire retardants unknown.

Other Vegetation Management Practices	Idaho	In fire-prone areas, agency manages vegetation using: • Bare ground treatment near guardrails. • Mowing and herbicide applications to reduce vegetation height and vigor.

Consultation With Fire Management Experts

Fire management experts from the Missoula Technology and Development Center and CAL FIRE were contacted to inquire about ground-applied fire retardants used as a preventive measure.

Missoula Technology and Development Center

Shirley Zylstra, supervisory program leader of Wildland Fire Chemical Systems at Missoula Technology and Development Center, discussed the use of fire retardants in this application. According to Zylstra, the USFS Qualified Products List (QPL) currently includes PHOS-CHEK long-term fire retardants, which adhere to vegetation longer and remain effective longer than other retardant applications. They are water-soluble, however; rain and wind can decrease their effectiveness.

Two products that are applied from ground-based equipment may be of interest to Caltrans:

- PHOS-CHEK LC95W, a light-colored product (the product has not been tested for weathering and durability).
- PHOS-CHEK Wildfire Home Defense, the noncolored PHOS-CHEK LC95 fire retardant marketed for residential use.

Zylstra also provided the USFS standard test procedure and specification for long-term fire retardants. USFS Specification 5100-304d,Long-Term Retardant, Wildland Firefighting, revised January 2020, includes this definition of *Fire Retardant, Long-Term*, on page 26:

> A product containing one or more inorganic salts to reduce the intensity of a fire. It contains water which serves to aid in uniform distribution of the retardant salts over the target fuel.
>
> The product continues to be an effective fire retardant after the water it originally contained has completely evaporated.
>
> (See page 14 for the citation for the January 2020 USFS specification.)

USFS is currently investigating a new category of pretreatment fire retardants for the QPL. These products could be used as preventives, however, testing protocols must be established before products can be recommended for this application. Testing protocols would need to evaluate a product's durability and its ability to withstand repeated applications of water, rain and UV exposure. Zylstra noted that the solubility factor of a product may preclude its use in pretreatment applications.

Zylstra noted that 10 years ago, USFS was required to conduct an environmental review of fire treatment chemicals. The current Environmental Impact Statement (EIS) addresses the use of retardant in a fire emergency, not frequent or continual use as is envisioned in a pretreatment application. Repeated application at the same location would be outside the EIS currently in place for USFS. (This EIS applies to USFS only, not to Caltrans or CAL FIRE.)

California Department of Forestry and Fire Protection (CAL FIRE)

Zylstra suggested contacting Don Cockrum, division chief of Tactical Air Operations at CAL FIRE. Cockrum reported that CAL FIRE does not use long-term fire retardants as a preventive measure. These products are used in aerial applications (with an air tanker or helicopter) to assist in the suppression and control of wildland fires. Ground application techniques are not used, and these products are not applied to roadsides. Instead, long-term fire retardants are used to help slow the spread of unwanted fires to allow ground forces to establish a control line, whether by a hose lay, hand crew, bulldozer or other method.

Supporting Documents

Numerous PHOS-CHEK resources and publications were provided by fire management experts or acquired through a limited literature search, including safety data sheets and technical bulletins. In addition, information is provided about proactive wildfire management technologies from Ladera Tech, Inc. (*Note*: Ladera Tech was recently acquired by Perimeter Solutions, the manufacturer of PHOS-CHEK products.) A November 2020 USFS listing of long-term retardants for wildland fire management includes a pretreatment category with two PHOS-CHEK products, noting that the pretreatment category "has not been evaluated for durability and weathering."

Related Research and Resources

An examination of domestic in-progress and completed research sought information that examined the pre-fire season applications of ground-applied fire retardants along roadsides and other open corridors as a preventive measure. The literature search also examined available information about the environmental impacts and regulatory considerations of fire retardants used in surface applications, including a search of publicly available resources from the California State Water Resources Control Board.

The literature search produced very little guidance on these topics. A September 2019 journal article examines the potential opportunities of shifting the use of fire retardants from reactive suppression to proactive prevention in high-risk landscapes (see page 15). (*Note*: Two of the authors invented the technology reported in the article; two authors founded Ladera Tech, which has licensed the technology from Stanford University.) A follow-up response to this research suggested the data was insufficient for these applications and required more study to understand the environmental impact, economic feasibility, and effectiveness through weathering and in combating approaching wildfire. The study authors responded that the retardant fluids used in the research were designed to prevent wildfires at locations where ignitions are historically known to originate. They argued that 84% of wildfires are strongly localized adjacent to roadsides and utilities infrastructure, and using retardants in a small area "could potentially prevent a majority of wildfires by averting them at their source" (see page 16).

A January 2020 U.S. Department of Interior standard presents the policy for surface applications of wildfire chemicals, with recommendations for dispersing these products near waterways and other avoidance areas (see page 16). The remaining resources address ecological considerations, including a 2020 USFS risk assessment of long-term fire retardants (see pages 17 and 18). A research study in progress by the U.S. Geological Survey's California Water Science Center will examine soil erosion in wildfire areas and the transport of sediment containing nutrients into streams and reservoirs to determine which nutrients are likely to increase in concentration and whether using fire retardants may exacerbate the situation (see page 18). Fire management measures from the California State Water Resources Control Board briefly address steps to reduce the adverse impact of fire retardants on water quality (see page 19).

Gaps in Findings

Experience with and information about the use of ground-applied long-term fire retardants as a preventive measure are very limited, as demonstrated in the results of the survey and literature search for this project. Only 12 of 50 state transportation agencies responded to the survey, and none reported having experience using ground-applied fire retardants on the highway system as a preventive measure to reduce wildfire risk. Recent research about the use of ground-applied fire retardants as a preventive measure instead of a reactive measure during a fire emergency was also very limited.

Next Steps

Moving forward, Caltrans could consider:

- Contacting respondents from transportation agencies in Colorado, Idaho and Montana to obtain more information about current practices and interest in using fire retardants as a preventive measure.
- Gathering information from state transportation agencies that did not respond to the survey, including agencies in other fire-prone states with summer drought conditions similar to those in California, and similar weathering or exposure conditions with regard to UV exposure. These states include Arizona, Nevada, New Mexico, Oregon and Washington. These agencies may have experience using ground-applied fire retardants or may be familiar with research or regulatory practices related to the use of these products.

- Engaging with Arizona DOT to learn more about the agency's use of fire retardants within the right of way, described in a 2014 news release (see page 20).
- Reviewing the PHOS-CHEK resources and publications associated with ground-based preventive applications.
- Tracking progress of the U.S. Geological Survey's California Water Science Center research study expected to conclude in 2021.

Detailed Findings

Background

The U.S. Forest Service (USFS) and California Department of Forestry and Fire Protection (CAL FIRE) use fire retardants during emergencies to reduce the intensity and spread of ongoing wildfires. These products are generally composed of water, fertilizer salts, thickening agents, coloring agents and other ingredients such as corrosion inhibitors and stabilizers that help slow the rates of fire spread. A combination of mechanisms promote cooling and coating of fuels, depleting the fire of oxygen and slowing the fuel combustion rate with inorganic salts by changing how fire burns. The USFS uses fire retardants in consultation with other federal agencies such as U.S. Fish and Wildlife and the National Oceanic and Atmospheric Administration (NOAA)–Fisheries to balance the need to protect critical or sensitive resources with the need to effectively control wildfire emergencies.

Fire retardants are typically applied aerially outside the active fire zone to control the spread of the fire. However, little is known about ground-based applications of fire-retardant products as a preventive measure before the onset of the fire season. The California Department of Transportation (Caltrans) is interested in the environmental and regulatory considerations of using ground-applied fire retardants on the roadside as a preventive measure in advance of the fire season. This information will help Caltrans determine whether to include application of these products in its vegetation management program.

To assist Caltrans in this information-gathering effort, CTC & Associates conducted an online survey of state departments of transportation (DOTs) about their knowledge of and experience with ground-based fire retardants as a preventive measure. The survey sought information about environmentally safe application practices and any best management practices that have been developed during the use of these products. Fire management experts from the Missoula Technology and Development Center and CAL FIRE were also consulted for information about ground-applied wildfire chemical systems used along roadsides. To supplement these findings, a literature search of domestic in-progress and completed research examined the pre-fire season applications of ground-applied fire retardants along roadsides and other open corridors as a preventive measure. Publicly available documents and other resources from the California State Water Resources Control Board were also reviewed.

This Preliminary Investigation presents the findings from these efforts in the following topic areas:

- Survey of practice.
- Consultation with fire management experts.
- Related research and resources.

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance. This committee's membership is national in scope and includes representatives from state transportation agencies in all 50 states and the District of Columbia. Survey questions are provided in Appendix A. The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Respondents from transportation agencies in 12 states responded to the survey:

- Alabama.
- Colorado.
- Florida.
- Idaho.
- Kansas.
- Maine.
- Maryland.
- Michigan.
- Missouri.
- Montana.
- Tennessee.
- Vermont.

None of these agencies use ground-applied fire retardants on the highway system as a preventive measure to reduce the risk of wildfire. A lack of significant wildfire activity was the primary reason cited by respondents from these agencies for not using the products. Other factors included a lack of information or understanding about the performance, impact and cost of these products, and the use of other vegetation management practices. Survey responses are summarized below by topic:

Lack of Wildfire Activity

- *Florida, Maine, Maryland and Vermont*: These states do not have a history of wildfires.
- *Alabama*. Except during droughts, fire has not been an issue in Alabama DOT's rights of way.
- *Michigan*. Snow-covered roadsides in winter and sufficient rainfall in most years create "verdant roadside vegetation" in the state.
- *Missouri*. Wildland fires are uncommon in Missouri. The periodic grass fire or forest fire is usually minimal and controlled quickly without the need for additional design considerations or strategies.
- *Tennessee*. The state does not have a history of significant wildfires along its right of way network. Fires have occurred in the National Park Service areas of eastern Tennessee and the Great Smoky Mountains National Park.

Operational Issues and Impacts

- *Colorado*. The state is experiencing a "massively active" wildfire season, and ground-applied fire retardants would help fire management. However, their use has not been addressed operationally. Environmental research is also needed to measure the impact of fire retardants on the roadside.
- *Florida*. More information is needed about the potential impacts of fire retardants.
- *Kansas*. The effect of these products on grass fires is unknown.
- *Montana*. The cost associated with the application of ground-based fire retardants is the primary reason these products are not used or considered.

Other Vegetation Management Practices

- *Idaho*. In fire-prone areas, the agency uses other methods to manage vegetation on roadsides:
    - Bare ground treatment near guardrails.
    - Mowing and herbicide applications to reduce vegetation height and vigor.

Consultation With Fire Management Experts

Information about the ground-based application of fire retardants and wildfire chemical systems was sought from the USFS Missoula Technology and Development Center, which provides technology transfer and equipment to federal and state agencies in support of public land management. Shirley Zylstra, supervisory program leader of Wildland Fire Chemical Systems at Missoula Technology and Development Center, discussed the use of long-term fire retardants.

USFS Specification 5100-304d,Long-Term Retardant, Wildland Firefighting, revised January 2020, includes this definition of *Fire Retardant, Long-Term*, on page 26:

> A product containing one or more inorganic salts to reduce the intensity of a fire. It contains water which serves to aid in uniform distribution of the retardant salts over the target fuel.
>
> The product continues to be an effective fire retardant after the water it originally contained has completely evaporated.
>
> (See page 14 for the citation for the January 2020 USFS specification.)

Zylstra also recommended contacting Don Cockrum, division chief of Tactical Air Operations at CAL FIRE, for details about a surface application of long-term fire retardants performed by the agency. Results from these consultations are summarized below.

Missoula Technology and Development Center

Long-Term Fire Retardants

The USFS Qualified Products List (QPL) currently includes PHOS-CHEK long-term fire retardants developed by Perimeter Solutions (see **Supporting Documents** below).These products adhere to vegetation longer and remain effective longer than other retardant applications. They are water-soluble, however; rain and wind can decrease their effectiveness.

Two products that are applied from ground-based equipment may be of interest to Caltrans:

- PHOS-CHEK LC95W, a light-colored product (the product has not been tested for weathering and durability).
- PHOS-CHEK Wildfire Home Defense, the noncolored PHOS-CHEK LC95 fire retardant marketed for residential use.

The USFS has also developed a standard test procedure and specification for long-term fire retardants (see **Supporting Documents** below). *Note*: According to Zylstra, while USFS does

occasionally perform localized ground applications, these applications are not similar in scope to the agency's aerial applications.

Pretreatment Fire Retardants

A new category of pretreatment fire retardants is under consideration for the USFS QPL. Before products can be recommended for use as preventives, however, testing protocols and other measures must be established to determine if they are more durable than formulations currently used in wildland fires. Durability and weathering will be evaluated, including how well the product withstands repeated applications of water, rain and UV exposure.

The protocols could be similar to the current tests used for long-term fire retardants with the added assessment of durability and weathering. Zylstra noted that the solubility factor of a product may preclude its use in preventive applications.

Environmental Impact Statement Restrictions

Ten years ago, USFS was required to conduct an environmental review of fire treatment chemicals. The current Environmental Impact Statement (EIS) addresses the use of retardant in a fire emergency, not frequent or continual use of a product as is envisioned in a preventive application. Repeated application at the same location would be outside the current EIS. *Note*: This EIS applies to the USFS only, not to Caltrans or CAL FIRE.

Further Recommendations

Zylstra suggested contacting Don Cockrum, division chief of Tactical Air Operations at CAL FIRE.

California Department of Forestry and Fire Protection (CAL FIRE)

According to Don Cockrum, CAL FIRE only uses fire retardants to suppress and control wildfires, not as a long-term preventive measure. Using these products allows forces on the ground to establish a control line. Fire retardants are only applied aerially (with an air tanker or helicopter), not from the ground or on roadsides.

Supporting Documents

Below are resources and publications provided by fire management experts or acquired through a limited literature search in two topic areas:

- Commercial product information.
- Testing and safety information.

Commercial Product Information

PHOS-CHEK LC95W, Perimeter Solutions, undated.
https://phoschek.com/product/phos-chek-lc95w/
From the web site: PHOS-CHEK LC95 fire retardants are concentrated liquids that mix readily with water by recirculation, agitation or with mechanical or electronic PHOS-CHEK liquid proportioning systems. PHOS-CHEK LC95 fire retardant and variants are the only liquid concentrate (LC) ammonium polyphosphate retardants that offer both the ease of mixing and handling of a liquid and the aerial drop advantages of a gum-thickened retardant. The elastic

nature of the thickener in PHOS-CHEK retardants reduces drift, dispersion and evaporation, and facilitates increased fuel coverage, wraparound and penetration through canopy and ladder fuels to ground vegetation. Recovery can exceed 90%.

PHOS-CHEK LC95 is available in [r]ed [i]ron [o]xide (R), [f]ugitive (F) and [u]ncolored (W). … Uncolored PHOS-CHEK LC95W is ideal for ground application where color is not required or [is] undesirable.

Related Resources:

PHOS-CHEK LC95: Long-Term Fire Retardant, Product Datasheet, Perimeter Solutions, 2019.
https://385xpfxe1e13almu7u8sj31b-wpengine.netdna-ssl.com/wp-content/uploads/2020/01/PC_LC95-Retardants_PCC-2019042-2.pdf
Product characteristics and applications are provided in this datasheet.

PHOS-CHEK LC95 Safety Data Sheet, Perimeter Solutions, August 2019.
https://385xpfxe1e13almu7u8sj31b-wpengine.netdna-ssl.com/wp-content/uploads/2020/01/SDS_PC_LC95W-Retardant-OSHA-WHMIS_2019-08-12_EN.pdf
The technical properties of this product are presented along with potential safety and environmental hazard information. Environmental precautions suggest preventing entry to sewers and public waters. Ecological information indicates the product may cause long-term adverse effects in the aquatic environment.

Fire Retardants Toxicological and Environmental Safety Frequently Asked Questions, Product Technical Bulletin, PHOS-CHEK Fire Retardants, Perimeter Solutions, October 2019.
https://385xpfxe1e13almu7u8sj31b-wpengine.netdna-ssl.com/wp-content/uploads/2020/01/PC_Retardant-Toxicological-Safety-FAQ_PCTB-2019002-0.pdf
Topics addressed in this technical bulletin include product biodegradability; health, safety and environmental testing; safety review by regulatory agencies; toxicity to fish and water-dwelling invertebrates; and the effects of residue on vegetation, domestic animals and wildlife.

PHOS-CHEK Wildfire Home Defense, Perimeter Solutions, undated.
https://perimeter-solutions.com/fire-safety/phos-chek-wildfire-home-defense/
From the web site: Our retardant is a long-term fire retardant that helps stop the spread of wildfires by reducing the combustibility of potential fuels. With the powerful and unpredictable nature of wildfires, this noncolored formula works by naturally changing the molecular composition of organic materials such as grass, wood and vegetation. This change ensures that they no longer serve as fuel, effectively slowing down the rate of spread of the fire. Used as directed, the formula is friendly to people and pets, as well as the environment.
….

PHOS-CHEK can help protect your property for months. Fuels applied properly will remain incombustible until rain washes the formula away.

Ground Applied: Long-Term Fire Retardant Ground Application, Perimeter Solutions, 2019.
https://385xpfxe1e13almu7u8sj31b-wpengine.netdna-ssl.com/wp-content/uploads/2020/01/PC_Ground-Applied-Brochure_PCC-2019019-0.pdf
PHOS-CHEK products suitable for surface applications are highlighted in this product brochure. Applications for ground-applied retardants include:

- Pretreatment of high-risk fire areas.
- Areas around critical infrastructure assets (communication towers and highway signage).
- Protection for fence posts, power poles, easements and rights of ways.
- Extension of roadway fire breaks.

Among the advantages of ground-applied retardant is that it "[c]an be applied hours, days, weeks and months in advance." Physical properties and recommended coverage levels are also provided.

Related Resources:

PHOS-CHEK, Perimeter Solutions, Inc., undated.
https://phoschek.com/
From the web site:

> Experts at Perimeter Solutions work side-by-side with fire management agencies in North America and across the world to provide safe and effective firefighting chemicals and to develop new products that meet the needs and desires of fire management personnel.

Access to product information, including safety data sheets and technical bulletins; services and equipment; and training are provided at the manufacturer's web site.

"Two Arizona Animal Rescue Organizations Deploying PHOS-CHEK Fire Retardant as Defense Against Nearby Wildfires," *PR Newswire*, July 8, 2020.
https://www.prnewswire.com/news-releases/two-arizona-animal-rescue-organizations-deploying-phos-chek-fire-retardant-as-defense-against-nearby-wildfires-301090112.html
From the news release: Perimeter Solutions announced that two of central Arizona's best known animal rescue organizations are employing a new approach to protecting their facilities and the animals they house, by using the same technology employed by the USDA Forest Service to slow the onslaught of wildfire in what is one of Arizona's worst fire seasons in memory. The Arizona Equine Rescue Organization (AERO), specializing in rescue and rehabilitation of horses and the Southwest Wildlife Conservation Center that shelters and cares for over a dozen animal species, will be applying Perimeter Solutions' PHOS-CHEK LC95W [f]ire [r]etardant on their respective properties in early July. PHOS-CHEK LC95W is a ground-applied version of the fire retardant best known as "that red stuff" used around the world in aerial firefighting operations. The fire retardant, which will be applied on vegetation and on vulnerable facilities, is designed to make each less likely to burn if contacted by flying embers. The two organizations, which [have] extensive experience supporting Arizona firefighting organizations with fire-related animal rescue, house hundreds of animals, many of which are not suited for evacuation. Both organizations look on the proactive use of ground-applied fire retardant as a demonstration project for property owners in an area that is home to thousands of difficult-to-evacuate animals.

Note: Below are citations for Ladera Tech and its PHOS-CHEK FORTIFY product. Perimeter Solutions acquired Ladera Tech in May 2020.

New Technology for Proactive Wildfire Management, Ladera Tech, Inc., 2020.
https://www.ladera.tech/
From the web page: To address the major limitations of current technologies, we have developed PHOS-CHEK FORTIFY, which can be deployed at sites of particularly high fire danger for the entire duration of a fire season, providing a protective barrier that can prevent a vast number of wildland fires from starting in the first place. PHOS-CHEK FORTIFY is powered by VISMOTECH, an environmentally benign hydrogel platform made from renewable resources that exhibits critical properties that are impossible with traditional hydrogels. PHOS-CHEK FORTIFY can be deployed using standard equipment for simple application to a diverse array of target fuels and enable season-long retention of polyphosphate retardants. This approach is impossible with current technologies.

Related Resource:

FORTIFY, Safety Data Sheet, Ladera Tech, Inc., July 2019.
https://static1.squarespace.com/static/5c7ebc2034c4e2a3b0a67d28/t/5d406fcbee19ed00013c080a/1564504013062/Fortify+SDS+V7.pdf
Composition information along with physical and chemical properties is included in this safety data sheet. Toxicity levels for zebra fish are provided but no other ecological or environmental information.

Testing and Safety Information

Wildland Fire Chemicals: Safety Data Sheets (SDS), Forest Service, U.S. Department of Agriculture, November 2020.
https://www.fs.fed.us/rm/fire/wfcs/msds.htm
This web page provides safety data sheets for products on the USFS Wildland Fire Chemicals QPL, including PHOS-CHEK products classified as long-term fire retardants.

Related Resource:

Wildland Fire Chemicals, Wildland Fire Chemical Systems, Forest Service, U.S. Department of Agriculture, undated.
https://www.fs.fed.us/rm/fire/wfcs/products/
Access to product information for PHOS-CHEK long-term fire retardants from the USFS QPL is provided on this web page.

Standard Test Procedure: Wildland Fire Chemicals, Wildland Fire Chemical Systems, Forest Service, U.S. Department of Agriculture, undated.
https://www.fs.fed.us/rm/fire/wfcs/tests/index.htm
From the introduction: All wildland fire chemical products must be evaluated and qualified prior to use. Several documents together describe the process and requirements for evaluating and qualifying each product type[:]

- The Manufacturer Submission Procedures for each product type explains how to submit [a] product and what information is required.

- The Specification for each product type contains the classification and performance requirements and a brief description of the test methods to be used.
- The Standard Test Procedures contain more detailed information for performing each of the required tests.

Long-Term Retardant, Wildland Firefighting, Specification 5100-304d, Forest Service, U.S. Department of Agriculture, January 7, 2020.
https://www.fs.fed.us/rm/fire/wfcs/documents/5100-304d_LTR_Final%20Draft_010720.pdf
From the scope: The long-term fire retardants described in this specification are for use in wildland fire management. They may be applied from aerial or ground application equipment. After mixing with water in the prescribed ratio, the mixed retardant is applied to slow the spread and reduce the intensity of the fire. Long-term retardants continue to be effective after the contained water has evaporated. Long-term retardant concentrates may be wet or dry.

Related Resource:

> **Long-Term Retardant for Wildland Fire Management**, Fire and Aviation Management, U.S. Forest Service, November 2020.
> https://www.fs.fed.us/rm/fire/wfcs/documents/2020-1105_qpl_ret.pdf
> The PHOS-CHEK long-term retardants listed in this table are qualified by USFS in accordance with Specification 5100-304d. Mix ratios and qualified applications are provided for each chemical. (Ground applications are fully qualified for all PHOS-CHEK products.)
>
> The table also lists a pretreatment category with two products (PHOS-CHEK LC-95-W and PHOS-CHEK LC-95A-Fx), noting that the pretreatment category “has not been evaluated for durability and weathering.”

Related Research and Resources

An examination of domestic in-progress and completed research sought information about the pre-fire season applications of ground-applied fire retardants along roadsides and other open corridors as a preventive measure. The literature search also examined available information about the environmental impacts and regulatory considerations of fire retardants used in surface applications, including publicly available resources from the California State Water Resources Control Board.

The literature search uncovered minimal guidance on the use of fire retardants in ground applications and no information related to environmental or regulatory issues in surface applications. A limited number of resources are provided that offer general guidance and research related to these issues based on the use of fire retardants during a fire, not as a preventive measure. These findings are presented below in the following topic areas:

- Pre-fire season use.
- Surface application guidance.
- Ecological considerations.
- Related resource.

Pre-Fire Season Use

"Wildfire Prevention Through Prophylactic Treatment of High-Risk Landscapes Using Viscoelastic Retardant Fluids," Anthony C. Yu, Hector Lopez Hernandez, Andrew H. Kim, Lyndsay M. Stapleton, Reuben J. Brand, Eric T. Mellor, Cameron P. Bauer, Gregory D. McCurdy, Albert J. Wolff III, Doreen Chan, Craig S. Criddle, Jesse D. Acosta and Eric A. Appel, *Proceedings of the National Academy of Sciences*, Vol. 116, No. 42, pages 20820-20827, September 2019.
https://www.pnas.org/content/pnas/116/42/20820.full.pdf
From the abstract: Polyphosphate fire retardants are a critical tactical resource for fighting fires in the wildland and in the wildland–urban interface. Yet, application of these retardants is limited to emergency suppression strategies because current formulations cannot retain fire retardants on target vegetation for extended periods of time through environmental exposure and weathering. New retardant formulations with persistent retention to target vegetation throughout the peak fire season would enable methodical, prophylactic treatment strategies of landscapes at high risk of wildfires through prolonged prevention of ignition and continual impediment to active flaming fronts. Here we develop a sprayable, environmentally benign viscoelastic fluid comprising biopolymers and colloidal silica to enhance adherence and retention of polyphosphate retardants on common wildfire-prone vegetation. These viscoelastic fluids exhibit appropriate wetting and rheological responses to enable robust retardant adherence to vegetation following spray application. Further, laboratory and pilot-scale burn studies establish that these materials drastically reduce ignition probability before and after simulated weathering events. Overall, these studies demonstrate how these materials actualize opportunities to shift the approach of retardant-based wildfire management from reactive suppression to proactive prevention at the source of ignitions.

Related Resources:

Letter: No Evidence of Suitability of Prophylactic Fluids for Wildfire Prevention at Landscape Scales, Cristina Santin, Stefan H. Doerr, Juli G. Pausas, Emma C. Underwood and Hugh D. Safford, *Proceedings of the National Academy of Sciences*, Vol. 117, No. 10, pages 5103-5104, March 2020.
https://www.pnas.org/content/pnas/117/10/5103.full.pdf
From the letter: Yu et al. propose a viscoelastic fluid as a prophylactic fire-retardant treatment in landscapes at high risk of wildfires. We argue that, while the idea is worth exploring further, their data do not support its suitability for real landscape-scale applications.
….

While research on alternative mitigation treatments, such as that presented by Yu et al., is essential, their application should not be promoted without a proper evaluation of effectiveness, environmental impact, practical and economic feasibility, and without considering their usefulness in comparison—and integration—with conventional fuel treatments and fire prevention approaches whose costs and benefits are already well understood.

Letter: Reply to Santin et al.: Viscoelastic Retardant Fluids Enable Treatments to Prevent Wildfire on Landscapes Subject to Routine Ignitions, Eric A. Appel, Craig S. Criddle, Jesse D. Acosta and Anthony C. Yu, *Proceedings of the National Academy of Sciences*, Vol. 117, No. 10, pages 5105-5106, March 2020.
https://www.pnas.org/content/pnas/117/10/5105.full.pdf
From the letter: In response to our paper, Santin et al. state that while our approach is worthy of further exploration we did not provide sufficient support for suitability of these fluids at large scale. Specifically, they question the 1) environmental impact, 2) effectiveness through weathering, 3) economic feasibility, and 4) effectiveness in combating approaching wildfire.

Several of Santın et al.'s critiques arise from a severe misunderstanding of the intended use of our retardant fluids, highlighted by their suggestion that preventative treatments would need to cover half of California and combat high-intensity wildfires. Our retardant fluids were designed for prevention of wildfires at locations where ignitions are historically known to originate. While it is true that "fire-threat" maps indicate that much of the state is endangered by severe wildfire events, 84% of wildfires are strongly localized adjacent to roadsides and utilities infrastructure—"high-risk" landscapes subject to routine ignitions (figure 1 in ref. 1). Thus, prophylactic treatment of a small amount of land, such as a 20-[foot]-wide treatment adjacent to the roadside, could potentially prevent a majority of wildfires by averting them at their source.

Surface Application Guidance

"Suppression Chemicals and Delivery Systems," Chapter 12, Interagency Standards for Fire and Fire Aviation Operations, Department of the Interior, Department of Agriculture, January 2020.
https://www.nifc.gov/PUBLICATIONS/redbook/2020/Chapter12.pdf
Although this updated manual primarily focuses on aerial applications of long-term retardants, ground delivery is discussed briefly throughout the chapter, including the interagency policy for aerial and ground delivery of wildland fire chemicals near waterways and other avoidance areas (beginning on page 273 of the report, page 3 of the PDF):

This policy is an expansion and update for the 2000 and 2009 updated Guidelines for Aerial Delivery of all wildland fire chemicals, including retardant, foam and water enhancers, which were established and approved by the Forest Service (FS) and the Department of the Interior (DOI). The policy includes additional avoidance areas (both aquatic and terrestrial) for aerial delivery of fire chemicals as designated by individual agencies and includes additional FS reporting requirements.

….

Ground Delivery Policy: Avoid application of all wildland fire chemicals into waterways.*

* Delivery on the ground provides for more precise delivery of fire chemicals to target areas. Thus delivery is allowed within the aquatic mapped avoidance areas provided chemicals do not reach the waterway. Because there is potential for TEPCS [threatened, endangered, proposed, candidate or sensitive species], their designated critical habitats or other resources such as cultural or heritage areas to occur in waterway buffers or additional mapped avoidance areas, it is advised that a resource advisor be consulted prior to application to determine best action or the potential for environmental effects.

Ecological Considerations

Ecological Risk Assessment of Wildland Fire-Fighting Chemicals: Long-Term Fire Retardants, Fire and Aviation Management, National Technology and Development Program, U.S. Forest Service, June 2020.
https://www.fs.fed.us/rm/fire/wfcs/documents/NONCONFIDENTIAL%20EcoRA-Retardants-June2020.pdf
From the executive summary:

The U.S. Forest Service uses a variety of fire-fighting chemicals to aid in the suppression of fire in wildlands. These products can be categorized as long-term retardants, Class A foams, and water enhancers. This chemical toxicity risk assessment of the long-term retardants examined their potential impacts on terrestrial wildlife and aquatic species. Exposures from both planned and accidental releases were considered, including on-target drops to terrestrial areas, accidental or unavoidable drops across water bodies, and accidental spills to a stream during aerial or ground transport.

This risk assessment evaluates the toxicological effects associated with chemical exposure, that is, the direct effects of chemical toxicity, using methodologies established by the U.S. Environmental Protection Agency. A risk assessment is different from and is only one component of a comprehensive impact assessment of all types of possible effects from an action on wildlife and the environment, including aircraft noise, cumulative impacts, habitat effects, and other direct or indirect effects. Consultation under Section 7 of the Endangered Species Act and environmental assessments or environmental impact statements pursuant to the National Environmental Policy Act consider chemical toxicity as well as other potential effects to make management decisions.

Appendix A assesses the ecological risks of retardants on the QPL to terrestrial and aquatic wildlife (beginning on page 44 of the report, page 49 of the PDF).

Related Resource:

Risk Assessments—Wildland Fire Chemicals, Wildland Fire Chemical Systems, Forest Service, U.S. Department of Agriculture, undated.
https://www.fs.fed.us/rm/fire/wfcs/ras.htm
Access to ecological and human health risk assessments is provided on this web page.

Air Quality

"Pesticides, Wildfire Suppression Chemicals and California Wildfires: A Human Health Perspective," Sarah A. Carratt, Cameron H. Flayer, Michelle E. Kossack and Jerold A. Last, *Current Topics in Toxicology*, Vol. 13, pages 1-12, 2017.
https://escholarship.org/uc/item/7rh1s9z8#main
From the abstract: This review summarizes what we currently know about the contribution of pesticides and wildfire suppression chemicals to wildfire-induced human health effects. In California there is heavy use of pesticides in agricultural settings and at the urban interface. When wildfires burn land treated with pesticide, these chemicals and their combustion products are volatilized and can be inhaled by humans. These constituents can be transported long distances in smoke, although those at the highest risk for exposure are near the wildfire source. Toxicity of some pesticides by inhalation has been demonstrated, although the health effects of pesticide combustion products in smoke have not been characterized. In order to effectively fight wildfires, large volumes of wildfire suppression chemicals are used. Wildfire suppression chemicals include retardants, for long-term application, and foams, for short-term application. Based on the available data, foams are more likely to have an impact on human health than retardants. Moreover, foams tend to be applied at the urban interface, while the retardants are generally applied in remote areas. Understanding the health effects of the compounds we choose to introduce into our environment and how they alter and are altered by extreme events like wildfires is an important consideration for fire and land management. Our investigation has uncovered that there are significant data gaps in this area.

Water Quality and Aquatic Species

Research in Progress

Effects of Wildfire and Fire Retardants on Nutrient Transport in California Watersheds, California Water Science Center, U.S. Geological Survey, start date: June 2020; expected completion date: 2021.
Project overview at https://www.usgs.gov/centers/ca-water/science/effects-wildfire-and-fire-retardants-nutrient-transport-california?qt-science_center_objects=0#qt-science_center_objects
From the project overview: Large wildfires have increased in size and frequency in the western United States over the past several decades. This has led to increased soil erosion and the transport of sediment containing nutrients into streams and reservoirs. Excess nutrients typically lead to the increased production of algae which can then lead to low levels of dissolved oxygen. This degrades the habitat for fish and wildlife, as well as having negative impacts on the drinking water supply and human recreation.

In addition, each year millions of liters of fire-retardant chemicals are applied to wildfires across the nation. The use of these retardants could also have significant effects on downstream nutrients. The aim of this study will be to determine which nutrients are likely to increase in concentration in areas affected by wildfire in the western U.S., and whether the use of fire retardants may exacerbate the situation. Specifically, wildfires and related use of fire retardant

could have significant effects on downstream nutrients and related water-quality conditions in reservoirs owned and operated by the Bureau of Reclamation (BOR). A modeling approach could help the BOR implement best management practices to protect water quality and benefit the environment.

Guidance and Completed Research

"Fire Retardants," 2G—Fire Management, California State Water Resources Control Board, undated.
https://www.waterboards.ca.gov/water_issues/programs/nps/encyclopedia/2g_fire_mgmt.html
From the web page: The following management measures can be used to reduce the adverse impacts of fire on water quality:

> **Fire retardants**. Whenever possible, a 300-foot buffer should be left on both sides of a waterway when fire retardants are applied from the air. If it is necessary to apply retardant within the 300-foot zone, the application method that most accurately keeps the retardant from entering the stream should be used. Fire retardant chemicals that contain sodium ferrocyanide should be avoided because a recent study revealed that mixtures with the chemical can decompose to produce amounts of cyanide that exceed USEPA [U.S. Environmental Protection Agency] water quality guidelines for freshwater organisms.

"Toxicity of PHOS-CHEK LC-95A and 259F Fire Retardants to Ocean- and Stream-Type Chinook Salmon and Their Potential to Recover Before Seawater Entry," Joseph P. Dietrich, Ahna L. Van Gaest, Stacy A. Strickland, Greg P. Hutchinson, Alex B. Krupkin and Mary R. Arkoosh, *Science of the Total Environment*, Vol. 490, pages 610-621, August 2014. Citation at
https://www.sciencedirect.com/science/article/abs/pii/S0048969714007153?via%3Dihub
From the abstract:

> Long-term fire retardants are used to prevent the spread of wildland fire, but have inadvertently entered aquatic habitats and resulted in fish kills. We examined the toxicity of two fire retardant products; PHOS-CHEK 259F and LC-95A, on Chinook salmon with two different life histories, ocean-type and stream-type, at different stages of their development. Ocean-type Chinook outmigrate to the ocean as subyearlings while stream-type salmon overwinter in freshwater and outmigrate as yearlings. Ocean-type and stream-type salmon were exposed to the fire retardants prior to their parr to smolt transition (presmolts) as subyearlings (stream-type and ocean-type) and yearlings (stream-type only), as well as during their transition (smolts). The salmon were exposed to eight concentrations of each retardant and a control for 96 h[ours] to determine acute toxicity. Lethal concentration curves were modeled by logistic regression for each life history and life stage exposed to the two fire retardants. Among all life histories and life stages tested, PHOS-CHEK 259F was most toxic to stream-type salmon at smolt stage and PHOS-CHEK LC-95A was most toxic to ocean-type salmon at smolt stage. To determine the delayed effects of product exposures on fish health as well as for the potential of recovery, 24-hour seawater challenges were performed immediately after fire retardant exposure, as well as after a recovery period. Previous PHOS-CHEK exposure reduced survival during seawater challenge among salmon from both life histories undergoing the parr-smolt transition and was more pronounced after PHOS-CHEK LC-95A exposure. However, this delayed effect was not observed 34 or more days after either PHOS-CHEK exposure. We conclude that accidental PHOS-CHEK LC-95A or 259F drops during salmon outmigration would have adverse impacts that extend beyond the acute mortality that occurs within the immediate drop and dilution areas.

Highlights from the article:

- LC-95A is lethal to 50% of Chinook salmon at 0.23% of the applied concentration.
- 259F is lethal to 50% of Chinook salmon at 0.09% of the applied concentration.
- Delayed mortality occurred in seawater after PHOS-CHEK exposure at smolt stage.
- Chinook salmon exposed to retardants as presmolts were not seawater-intolerant.
- Chinook salmon sensitivities varied with life stage and life history strategy.

Related Resource

ADOT Supports Efforts to Fight Wildfires, News Release, Arizona Department of Transportation, July 15, 2014.
https://azdot.gov/adot-news/adot-supports-efforts-fight-wildfires
Although only general information is provided, this news release refers to Arizona DOT's use of fire retardants within the right of way. *From the news release*:

> Among the different agencies and organizations involved in fighting wildfires, the Arizona Department of Transportation may not come to mind. However, ADOT [Arizona DOT] is active in helping to prevent wildfires both before and during wildfire season.
> During the winter and spring seasons, ADOT crews mow down vegetation along the highway shoulders. Crews also engage in brush removal, thinning trees and spraying fire retardant within the ADOT right of way in order to prevent a fire or slow the spread of one.

Contacts

CTC contacted the individuals below to gather information for this investigation.

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Appendix A: Survey Questions

The following survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance.

Survey on Surface Applications of Fire Retardants

Note: The response to the question below determined how a respondent was directed through the survey.

(Required) Does your agency use **ground-applied** fire retardants on the highway system as a **preventive measure** to reduce the risk of wildfire?

Response Options:

- Yes. Our agency **uses** ground-applied fire retardants on the highway system as a preventive measure. (Directed the respondent to the **Use of Ground-Applied Fire Retardants Along the Roadside** section of the survey and the sections that follow it.)
- No. While our agency does not use ground-applied fire retardants on the highway system as a preventive measure, it **is considering** this application. (Directed the respondent to the **Agencies Considering the Use of Surface Applications of Fire Retardants** section of the survey.)
- No. Our agency **has never used** and **is not considering** using ground-applied fire retardants on the highway system as a preventive measure. (Directed the respondent to the **Agencies Not Using Surface Applications of Fire Retardants** section of the survey.)

Agencies Not Using Surface Applications of Fire Retardants

Please briefly describe why your agency is not using or considering using ground-applied fire retardants to reduce the risk of wildfire.

Note: After responding to the question above, the respondent was directed to the **Wrap-Up** section of the survey.

Agencies Considering the Use of Surface Applications of Fire Retardants

Please briefly describe your agency's discussions or plans to use ground-applied fire retardants to reduce the risk of wildfire.

Note: After responding to the question above, the respondent was directed to the **Wrap-Up** section of the survey.

Use of Ground-Applied Fire Retardants Along the Roadside

Background

1. Please provide the name of the ground-applied fire-retardant product(s) that your agency has used successfully as preventive measures to reduce fire risk along the roadside. Please include the name of the vendor supplying the product.

2. Does your agency use ground-based fire retardants to mitigate fire risk in the right of way?
    - No (Please skip to **Question 3**.)
    - Yes (Please answer **Question 2A**.)

2A. Does your agency use ground-based fire retardants to mitigate fire risk in areas outside of the right of way?
    - No
    - Yes (Please briefly describe these areas.)

3. Has your agency established protocols and best management practices for safe and effective application of the product on the roadside surface?
    - No
    - Yes (Please briefly describe these protocols and best management practices.)

4. If available, please provide links to documentation about the ground-applied fire-retardant product(s) and practices that your agency uses. Send any files not available online to chris.kline@ctcandassociates.com.

Environmental Issues

1. When the fire retardant is applied, what is the distance that must be maintained between the fire-retardant application and water sources?
2. Do the ground-based fire retardants that your agency uses negatively impact **water quality** or **aquatic resources**?
    - No
    - Yes (Please briefly describe the negative impact.)
3. Do the ground-based fire retardants that your agency uses negatively impact **endangered plant species**?
    - No
    - Yes (Please briefly describe the negative impact.)
4. Do the ground-based fire retardants that your agency uses negatively impact other **wildlife** or **wildlife habitat**?
    - No
    - Yes (Please briefly describe the negative impact.)
5. Has an Environmental Impact Statement, endangered species consultation or permitting been performed for the use of the product?
    - No (Please skip to **Question 6**.)
    - Yes (Please answer **Questions 5A and 5B**.)

5A. Please briefly describe the studies, consultation or permits and their effects.

5B. Were the studies, consultation or permits for blanket use or for individual application?
    - Blanket use
    - Individual application
    - Other (Please briefly describe the application.)

6. Does your agency have written regulatory approval of these products?
    - No
    - Yes (Please provide links to the written approval of these products. Send any files not available online to chris.kline@ctcandassociates.com.)

7. Does your agency use environmental clearance processes to ensure compliance with environmental laws and regulations?
    - No
    - Yes (Please briefly describe these processes.)
8. Are you aware of any current research or published studies that investigate the environmental impacts of ground-applied fire retardants as a preventive measure?
    - No
    - Yes (Please provide links to a description of the research or to the studies. Send any files not available online to chris.kline@ctcandassociates.com.)
9. Has your agency developed guidelines other than the best management practices mentioned above for using fire retardants as a preventive measure in a way that avoids, minimizes or mitigates adverse environmental impacts?
    - No
    - Yes (Please provide links to these guidelines. Send any files not available online to chris.kline@ctcandassociates.com.)

Regulatory Issues

1. Please describe the regulatory permit obligations your agency must meet when using ground-applied fire retardants as a preventive measure (not in an active fire).
2. Have any of the fire-retardant products used by your agency received approval from local, state or federal environmental regulatory agencies to prevent fire starts from occurring along the roadside?
    - No (Please skip to the **Assessment and Recommendations** section of the survey.)
    - Yes (Please answer **Question 2A** below.)

2A. Please briefly describe these exempted products and the requirements associated with these exemptions.

Assessment and Recommendations

1. What successes has your agency experienced with the use of ground-applied fire retardants as a preventive measure?
2. What challenges has your agency experienced with the use of ground-applied fire retardants as a preventive measure?
3. What are your top three recommendations for other agencies considering the use of ground-applied fire retardants as a preventive measure?
4. Please provide links to documents associated with your agency's use of ground-applied fire retardants as a preventive measure (other than those you have already provided). Send any files not available online to chris.kline@ctcandassociates.com.

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.