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FOAM APPLICATIONS FOR WILDLAND & URBAN FIRE MANAGEMENT

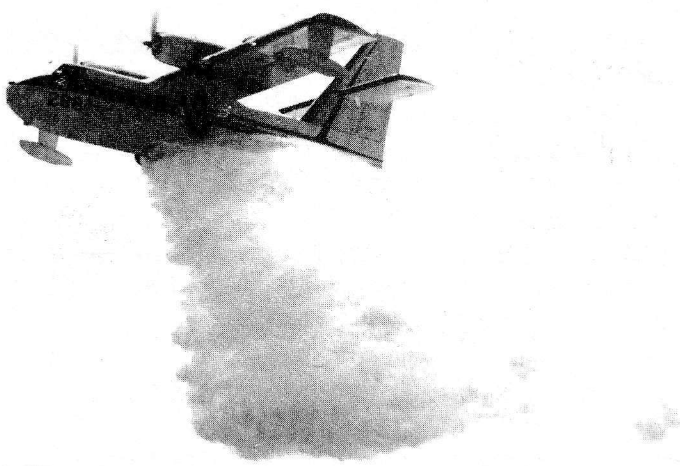
Prepared by: **NWCG Fire Equipment Working Team's Task Group for International/Interagency Foams and Applications Systems**

NATIONAL WILDFIRE COORDINATING GROUP

Canadian Committe on Forest Fire Management
Comité canadien de gestion des feux de forêt
CCFFM
CCGFF

International Wildland Fire Foam Symposium and Workshop

Thunder Bay, Ontario, Canada—May 3-7, 1994



Ontario Ministry of Natural Resources Canadair CL-215 making demonstration foam drop during the International Wildland Fire Foam Symposium and Workshop.

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INTRODUCTION

An International Wildland Fire Foam Symposium and Workshop was held May 3-7, 1994, in Thunder Bay, Ontario, Canada. The Symposium was sponsored by the National Wildfire Coordinating Group (NWCG) and by the Canadian Committee on Forest Fire Management (CCFFM) through its Forest Fire Equipment Working Group (FFEWG). The stated objectives of the Symposium were to:

1. Review the state-of-the-art in wildland fire foam research, development, and application

2. Assess progress that has been made in R & D and application since the International Symposium conducted in Denver, Colorado in 1988

3. Identify and prioritize needs and/or areas for future work

4. Make appropriate recommendations for action.

This newsletter begins with a short history of the International Foam Task Group by "Doc" Smith, Chairperson. It includes abstracts of professional papers presented during the Symposium and biographical sketches of the presenters. Based on the information obtained from the professional papers presented, the participants broke into four groups to make recommendations for guidance of future efforts in foam application and use. The participant groups were assigned the topics of Foam Properties, Foam Effectiveness, Foam and the Environment, and Foam Application and Use. A rough draft of these important recommendations is included on pages 31-35.

The Symposium was followed by a Foam Tactics and Applications Workshop, sponsored by the Canadian Committee on Forest Fire Management, and was dedicated to an exchange of information between forest fire management agencies and industry representatives. After vendor presentations, session participants had the opportunity to tour company displays and talk with company representatives individually.

The second part of the Workshop included presentations by several Canadian and American agencies on individual foam programs, several field operations demonstrations, and a panel discussion that led to the view that it is now up to individual agencies to explore the future use of foam within their fire management program. The final conclusion of the Workshop was that the required information on most aspects of foam is available and that this information must be packaged together in a proper manner that meets the needs of all agencies and industry.

"In Order To Know Where We Are Going—It Is Helpful To Know Where We Have Been"

A brief history of the
INTERNATIONAL FOAM TASK GROUP
by Hiram B. "Doc" Smith, Chairperson

The idea of a group to deal with issues of foam in an interagency/international context first surfaced with the NWCG Fire Equipment Working Team (FEWT) at a meeting in Grand Canyon National Park during the Spring of 1987. FEWT appointed a Chairperson (Doc Smith, Fire Staff Officer for the Kaibab National Forest), suggested a number of people for possible membership, and gave the group the charge: "CORRAL FOAM ."

The first organizational meeting was held in **Redding, California in the Fall of 1987.** They formalized the Charter into four main functions:

- Improve communications and cooperation.
- Get agreement on questions and concerns.
- Guide establishment of performance requirements.
- Provide communications, training, direction, and support to all users.

In Redding the Foam Task Group was more formally organized. It became:

- International
- Interagency
- Interdisciplinary including:

Wildlands	Aviation
Interface	Ground
Urban	Engine (trucks)

At Redding the International Foam Task Group set up an action plan to:

- Improve communications - The Foam Newsletter was born. (Three issues were published right away.)
- Agreement on questions and concerns was addressed by starting the planning for a workshop to be in Denver during June of 1988.
- There was the beginning of training concepts starting with the Abbotsford International Workshop in the Fall of 1987. The Rochna/Schlobohm training sessions developed into the interagency format that has served so well.

The Denver Workshop, June 6, 1988

The Workshop was conceived, planned, and carried out by the International Foam Task Group (with a lot of help from others).

The proceedings of the Workshop were published by Petawawa National Forestry Institute of the Canadian Forest Service in the form of the "BLUE BOOK."

The BLUE BOOK provided guidance for a number of agencies, groups, and functional workers. The guidance included San Dimas, NIFC, Missoula Fire Lab, Petawawa National Forestry Institute, Foam Task Group, California Department of Forestry and Fire Protection, Florida Division of Forestry and many others.

The BLUE BOOK provided guidance applications, nozzles, proportioners, training, videos, aviation, concentrate, and the tactics.

The Denver Workshop provided guidance for several years and was thus a real success.

The Foam Newsletter

The Foam Newsletter now has 12 issues (this one makes number 13). The first five issues have had to be reprinted due to demand. There are 134 different articles in the first 12 issues and over 68,500 copies have been distributed in the U.S. and Canada.

Videos

The Fire Equipment Working Team through the Foam Task Group has produced a number of short videos that can be used in training or other demonstrations. They include:

- Introduction to Class A Foam, produced in 1989

- Proportioners, produced in 1992

- Nozzles, produced in 1992

- Properties of Foam, produced in 1993

- CAFS, produced in 1993

- Tactics, due out in 1994.

These videos total 103 minutes of very relative information.

Publications

The Fire Equipment Working Team through the Foam Task Group has published two very informative publications.

The FOAM vs FIRE Primer

The FOAM vs FIRE Class A Foam

Another publication, FOAM vs FIRE Aerial Applications is due out in 1995.

There have been a number of other items that have either been influenced or sponsored by the Foam Task Group.

- Foam Kit part of the NFES cache. A kit containing a proportioner, nozzles, foam, and a few other components.

- Foam Bibliography 1991. A scientific compilation of around a thousand articles about foam. This is on a diskette using the software "Procite." A copy can be obtained from the Fire Lab in Missoula.

- Input into NFPA 298, the NFPA foam standard.

- The Foam Task Group has developed the International Foam Specification 1992.

- The Foam Task Group assisted with the **International Foam Symposium In Thunder Bay, Ontario, Canada.**

Training

The Foam Task Group has provided coordination and direction for the NIFC training that Ron Rochna and Paul Schlobohm have developed. They have conducted three International Workshops and some dozen workshops across the U.S. through the BLM and other agencies.

Ron Rochna and Paul Schlobohm developed a "Training Cadre" early on to help spread the word. They also developed training materials and rough lesson plans for the cadre to utilize.

Summary

The business of FOAM has come a long way since the Spring of 1987! Today there are many users of foam in lots of places, in lots of ways.

It is used in the WILDLANDS, the INTERFACE, the URBAN AREAS.

It is used both AERIALLY and from the GROUND.

It is used in STRUCTURE protection.

It is used in the USA, CANADA, FRANCE, GERMANY, AUSTRALIA, SPAIN, ITALY, and many other places.

There is INTERNATIONAL and INTERAGENCY COOPERATION.

We have good direction, excellent hardware, superior training aids, and a cost effective foam program.

Foam Today Is Pretty Much "In The Corral."

International Wildland Fire Foam Symposium

Thunder Bay, Ontario, May 3-5, 1994

An International Wildland Fire Foam Symposium, sponsored by the National Wildfire Coordinating Group (NWCG) through its Fire Equipment Working Team (FEWT) and by the Canadian Committee on Forest Fire Management (CCFFM) through its Forest Fire Equipment Working Group (FFEWG). The Symposium was jointly chaired by Bob Joens and Gordon Ramsey. The Steering Committee was comprised of Sig Palm, Paul McBay, Jim Stumpf, Doc Smith, Reidar Vollebekk, Chuck George, Bob Bailey, Ed Bons, and Doug Higgins.

AGENDA

Monday, May 2

1900 - 2200	Registration and Icebreaker - Scandia I	

Tuesday, May 3

0730 - 0830	Late Registration	
0830	Symposium Opening	Gordon Ramsey, CFS/PNFI
	Official Welcome	Cam Clark, NW Regional Director, OMNR
	Keynote Address	Karen Aquino, Director of Aviation, Flood, and Fire, OMNR
	Introductions	Gordon Ramsey, CFS/PNFI
	General Symposium Information	Ed Bons, OMNR
	Overview of Symposium	Bob Joens, USDA Forest Service, WO

<u>Background</u>

(Unit Leader, Bob Joens)

Review of Denver Meeting: Identified Needs and Direction
Post-Denver Meeting Accomplishments
Doc Smith, USDA Forest Service, Kaibab, NF

Status: International Wildland Fire Foam Specification and NFPA 298-Foam Chemicals For Fire Control - Revision Update
Chuck George, USDA Forest Service, NWST

1000	Break	

1015 <u>Properties and Effectiveness</u>

Unit Leaders: Bob Bailey, NWT, DRR and Cecilia Johnson, USDA Forest Service, NWST

Efforts in Characterizing Wildland Fire Foams
Cecilia Johnson, USDA Forest Service, NWST

Suppression /Extinguishing Effectiveness (Water/Foam Comparison)

NFPA Recent and Future Studies
Rich Bielen, NFPA

U.S. Army Studies (Ft. Belvoir)
Sam Duncan, U.S. Army

Underwriter Laboratories (UL) Studies
Bill Carey, UL

1130 Lunch

1245 NIST Studies
Dan Madrzykowski, NIST

NRC Studies: Performance of Compressed Air Class A Foam in Fixed Systems
Andrew K. Kim, Bogdan Dlugogorski, George F. Crampton, and Jack R. Mawhinney

Quantative Evaluation of Enhanced Water Fire Suppression

Past and Future Class A Foam Crib Burns and Natural Fuel Burn Tests
Bruce Edwards, Fire Tech Engineering, BC

Foam Enhanced Retardants - Operational Burns Trials
Judy Beck, British Columbia, Ministry of Forests

1415 Break

1430 <u>Application and Use</u>

Unit Leaders: Sig Palm, USDA Forest Service, SDTDC and Doug Higgins, CFS, PNFI

History of Foam Use In Canada
Randy Lafferty, C.O.F.I. of BC

Summary of Wildland Fire Foam in Canada
Bob Bailey, NWT, DRR

Effectiveness and Application of Foam in Spain
Ricardo Velez Munoz, ICONA (Spain)

Acceptance of Foam Use in Fire Suppression in British Columbia
Bob Beck, BC, Ministry of Forests

Foam Use in the Province of Quebec
Francois Lefebvre, SOPFEU Quebec

Cost-Effectiveness Analysis in Considering Fire Suppression Alternatives
Dave Martell, University of Toronto

Indirect Tactical Applications with Foam
Paul Schlobohm, BLM, NIFC

CAFS Power Systems and Proportioning Equipment Performance
Dan McKenzie, USDA Forest Service, SDTDC

1700 Close of Day

1830 Banquet

Wednesday, May 4

0800 Application and Use

Utilization of Foam from Water Scooping Aircraft in Ontario
Gordon Luke, OMNR

Environmental
Unit Leaders: Paul McBay, OMNR and Chuck George, NWST

The Ecological Impact of Fire Protection
Luc Duchesne, CFS, PNFI

FS Risk Assessment Study/Labat-Anderson, Inc.

- Human Health Risk Assessment
  Chris Boivin, LAI

- Ecological Risk Assessment
  Cyndi Bailor, LAI

Toxicity, Health and Safety of Wildland Fire Foams
Bob Sabol, Stillmeadow Laboratories

0940 Break

1000 Toxicity of Foams to Plant and Animal Communities

Overview of NBS Recent and Planned Studies
Susan Finger, USDI, NBS, NFCRC

Terrestrial Vegetation Response to Silv-Ex Application
Diane Larson, USDI, NBS, NPWRC

Toxicity of Fire Retardant Chemicals to Wildlife Species
Nimish B. Vyas, USDI, NBS, PWRC

Toxicity of Fire Retardant Chemicals to Aquatic Organisms
Steven J. Hamilton, USDI, NBS, NFCRC

Toxicity of Fire Suppressant Foams to the Aquatic Community
Barry C. Poulton, USDI, NBS, NFCRC

1130 Quebec Ecotoxicological Study On Fire Extinguishing Foams
Robert Langevin, Quebec Ministere des Ressources Naturelles

1150 Lunch

1300 Symposium Committee Workshops
Unit Leaders: Bob Joens and Gordon Ramsey

Properties and Effectiveness
Environmental
Application and Use
Others as Needed

1700 End of Day

Thursday, May 5

0800 Reports from Symposium Workshop Committees

Discussion

Recommendations/Conclusions

Wrap Up and Evaluation

1130 End of International Wildland Fire Foam Symposium and Workshop

Post Symposium Activities

1330-1800 Vendor Displays and Presentations

ABSTRACTS

International Wildland Fire Foam Symposium

Thunder Bay, Ontario, Canada

May 3-5, 1994

Following are abstracts of professional papers presented at the Symposium. Complete proceedings are being prepared and will be available about December 1, 1994, from:

Gordon S. Ramsey
Canadian Forest Service
Petawawa National Forestry Institute
P.O. Box 2000
Chalk River, Ontario, Canada K0J 1J0

Summary of Wildland Fire Foam in Canada

Submitted by: R.P. (Bob) Bailey
Director, Forest Fire Management
Department of Renewable Resources
Government of the Northwest Territories

Abstract:-

The results of a 1992 National Survey of Use of Class A Foam for Wildland Fire Management prepared for the Forest Fire Foam Research Task Group, Canadian Committee on Forest Fire Management are presented. Eighteen companies and agencies from across Canada responded to a questionnaire on foam use. The questions posed included delivery volumes, methods, foam effectiveness, environmental concerns, and handling problems. Thirteen hypotheses on the use of Class A foams were developed and tested against the responses received. A number of charts and graphs on use and a selected bibliography are also presented.

Forest Service Risk Assessment Study: Ecological Risk Assessment

Submitted by: Cyndi Bailor
Labat-Anderson Inc.
Arlington, Virginia

Abstract:-

This report describes the methodology and components of ecological risk assessments, as currently proposed by the U.S. Environmental Protection Agency, and details the results of the risk assessment conducted for the Forest Service on fire suppression chemicals. The assessment examined seven different regions and corresponding ecosystems to assess the impacts of long-term fire retardants and firefighting foams. Representative soil and stream data were collected or estimated, and fate and transport modeling was performed to estimate the impacts of average and upper end fire suppression chemical applications. The results of the risk assessment, and a discussion of the uncertainty involved, will conclude the presentation. The risk estimates indicate minimal effects to terrestrial species. Risk estimates for aquatic species show probable risks to aquatic species from both types of fire suppression chemicals under accident scenarios. Firefighting foams are generally more toxic to aquatic species than long-term retardants. Risks estimates from average scenarios indicate that site-specific characteristics greatly affect the potential for adverse effects. These characteristics include soil type, slope, stream pH, soil permeability, and type of species present. Modeling results contain a large degree of uncertainty; many of the important physical and chemical parameters for the formulations being modeled were unavailable and were therefore estimated.

Evaluating the Effectiveness of Retardant and Foam Composites

Submitted by: Judi Beck, Jeff Berry, and Kevin Wallinger
British Columbia, Ministry of Forests
Protection Branch
2nd Floor, Bastion Square
Victoria, BC

Abstract:-

Due to escalating costs, decreasing budgets and the need to increase operational efficiencies, the cost and effectiveness of aerial retardant programs have been under scrutiny in recent years. Several operational trials were conducted in British Columbia in 1988 to evaluate the suppression effectiveness of retardant and foam composites. These preliminary trials indicated that retardant foam composites may offer a number of advantages over unthickened retardant. When used in airtanker operations, retardant foam composites are thought to provide the following benefits over retardant alone: the drop pattern is more contiguous and coverage levels are more uniform; reduced retardant losses due to drift are incurred; canopy penetration is superior; fuel coverage through wrap around and drip is improved within standing timber; the perimeter of the drop is sharp and well defined in contrast to the dispersed edge of conventional retardant; and the visibility of the composite, both on the ground and from the air, is enhanced significantly.

More rigorous study is required to substantiate these preliminary findings and to address other issues related to the use of retardant foam composites. The current study has been initiated to determine if the effectiveness of long-term retardant at various concentrations (5 parts water to 1 part liquid concentrate, 8:1, 11:1 and 15:1) is improved when 0.3% Class A foam is added. To compare the effectiveness of retardants and composites, eight plots (approximately 30 m in diameter) will be established for each of several burn trials, which will be conducted in a variety of fuel types. Rate of spread and intensity will be monitored to determine if product effectiveness, using a ground application system, varies with fire behavior characteristics. Burnt and unburnt vegetation responses will be measured to determine if retardants or composites have an adverse effect on growth. This paper details the methodology of the study and reports on the preliminary results of this work.

NFPRF Recent Studies and Future Studies

Submitted by: Richard P. Bielen, P.E.
National Fire Protection Research Foundation
1 Batterymarch Park
Quincy, Massachusetts

Abstract:-

Class A foam has been used very effectively to fight wildland fires. This success has raised many questions as to the effectiveness of Class A Foam on structural fires. The Research Foundation was approached to start a project which would quantify the effectiveness of Class A foam vs. water on Class A materials.

The Research Foundation has completed one phase of the project which examined and measured the effectiveness of Class A foam and CAF vs. water on the extinguishment and rekindle of wood crib fires, exposure protection of wood cribs, and retention properties on wood cribs.

Presently, the Research Foundation is conducting the next phase of the project which is to examine and measure the effectiveness of Class A foam and CAF vs. water in full scale room fire tests, with a UL 1626 residential fuel package and upholstered furniture.

Forest Service Risk Assessment Study: Human Health Risk Assessment

Submitted by: Christine Boivin
Labat-Anderson Inc.
Arlington, Virginia

Abstract:-

This report summarizes a quantitative assessment of the risks to human health as a result of exposure to four types of chemicals approved by the U.S. Forest Service for wildland fire suppression: Long-term retardants, foams, short-term retardants, and wetting agents. A hazard analysis was conducted for each chemical to determine an acceptable dose level, and this level was compared to the estimated doses to both workers and members of the public from both average and upper end scenarios. The results show a potential for risk to certain categories of workers from some, but not all, of the retardant and foam formulations currently approved. No risks were identified for members of the public from foams, but some retardant formulations were associated with potential risks. However, there is significant uncertainty in this analysis, primarily due to the limited toxicity database. The use history of these chemicals reveals only incidents of skin and eye irritation, and no reported cases of systemic toxicity.

Suppression/Extinguishing

Effectiveness of Class A Foams as compared to plain water

Submitted by: William M. Carey
Underwriter Laboratories Inc. (UL)
Northbrook, Illinois

Abstract:-

Underwriters Laboratories Inc. (UL) has recently conducted research projects involving a comparison of the effectiveness of Class A foam solutions to

plain water for the National Fire Protection Research Foundation (NFPRF) and the U.S. Army. Both series of tests were conducted at UL's main office and test station in Northbrook, IL.

The NFPRF project involved the conduct of a series of performance tests using plain water and a single Class A foam concentrate. The Class A foam concentrate was a mixture of three batches of the same foam and was supplied by the United States Forest Service. It was approved as a Wildland Firefighting Foam and neither the brand nor the manufacturer of the foam was known to UL or to the project participants.

By using a single Class A foam concentrate for all of the testing, variables such as solution concentration, foam generation method and expansion ratio could be compared to determine which variable or combination of variables had the greatest impact on the test results. In addition, a series of viscosity, specific gravity, surface tension and density tests were conducted on the Class A foam concentrate and foam solutions.

The performance tests consisted of conducting Class 20A wood crib fire, exposure protection and retention tests. For the Class 20A fire tests, Class A foam solution concentrations of 0.1, 0.3, and 0.5 percent were used. Foam was generated at a nominal expansion ratio of 5 using a standard, adjustable spray nozzle set to a straight stream position and at a nominal expansion ratio of 7.5 using an air-aspirated nozzle and compressed air foam (CAF). For the exposure protection and retention tests, solution concentrations of 0.3, 0.6, and 0.9 were used. Foam was generated at nominal expansion ratios of 7.5 and 15 using CAF equipment. Foam quality tests were conducted on each solution concentration and foam generation method as described in the Standard for Foam Chemicals For Wildland Fire Control, NFPA 298.

The results of this research project are described in a test report titled, "National Class A Foam Research Project Technical Report - Knockdown, Exposure and Retention Tests" dated December 1993. Copies of this report are available from NFPRF.

The United States Army Class A foam research project involved the conduct of performance tests using six Class A foams which had been approved by the U.S. Forest Service as Wildland Firefighting Foams. In addition, a UL Listed aqueous film forming foam (AFFF) was also investigated. All of the Class A foams were on the Army's Qualified Products List (QPL), yet no fire performance tests are required for a Class A foam to be included on the QPL. Therefore, it was desired to conduct a series of performance tests to determine the fire suppression performance characteristics of currently available Class A foams as compared to plain water.

The performance tests consisted of conducting Class 20A wood crib fire and exposure protection tests. For the Class 20A fire tests, plain water or Class A foam solution concentrations of 0.5 and 1.0 percent were used. Foam was generated at a nominal expansion ratio of 7.5 using a standard adjustable spray nozzle fitted with an air-aspirating adapter. For the exposure protection tests, a Class A foam solution of 0.5 percent was used and foam was generated using an air-aspirating nozzle. Foam quality tests were conducted on each Class A foam solution concentration and nozzle combination as described in the NFPA 298.

The results of these tests are contained in a report titled, "Report of Class A Foam Tests" dated February 1994, which was conducted for the Department of the Army, Belvoir Research, Development and Engineering Center, Fort Belvoir, VA.

Performance of Class A Compressed Air Foam from a Fixed System

Submitted by: Bogdan Z. Dlugogorski, Andrew K. Kim, and George P. Crampton
National Research Council
Institute for Research in Construction
Ottawa, Ontario K1A 0R6 Canada

Abstract:-

A prototype of a fixed system delivering Class A compressed air foam has been built and tested at the National Fire Laboratory. The system relies on a proprietary nozzle and foam distribution de-

signs. It incorporates new design features which allow to supply the compressed air foam to the fire at predetermined expansion ratios avoiding foam degeneration in the piping and in the nozzles themselves.

A series of experiments in open-space and in an enclosure was conducted to explore the suppression efficiency of the newly developed system. The fire scenarios included hydrocarbon pool and wood crib fires, in enclosures and in open spaces. Both low and high flashpoint liquid fuels were tested. Additional experiments were conducted with water mist (with and without foam additives) and with pendant sprinklers to compare the suppression characteristics of Class A compressed air foam system with the existing technologies.

The results indicate that Class A compressed air foam is an effective suppressant for Class A and B combustibles. If delivered at sufficiently high momentum, the foam is able to penetrate the fire plume reaching directly the seat of the fire. It can spread rapidly on the surface of liquid hydrocarbon fires (passing with ease through metal obstructions) and it blankets the burning surfaces of the cellulosic materials. This leads to a very rapid fire suppression. Class A compressed air foam is especially suitable for extinguishing of fires of low flashpoint hydrocarbons in large spaces (where water mist is less effective), and it significantly outperforms other suppressants in extinguishing wood crib fires, in closed and open spaces. When applied to heptane and diesel fuel fires, no difference in the suppression performance is observed between Class A and B compressed air foams; however, Class A foam solutions are less expensive to prepare than solutions of Class B foams. Thus it appears that fixed systems based on Class A compressed air foam are a viable alternative for Class B foam installations.

Ecological Impact of Fire Protection

Submitted by: Dr. Luc C. Duchesne
Canadian Forest Service
Petawawa National Forestry Institute
Chalk River, Ontario

Abstract:-

One of the most important emerging challenges facing forest managers in Canada is the development of ecosystem management plans that will preserve biodiversity, favour multiple use of forest lands, and promote sustainable use. For this, however, forest managers will need to reassess the benefits of fire protection. Whereas the implementation of fire protection in Canada at the turn of the century served to protect the life and the homes of people as well as valuable timber, fire protection may have significant ecological impacts on ecosystems. Such impacts were unimportant when Canadian forest management emphasized timber production but the advent of forest ecosystem management focuses on all ecosystem components and characteristics. Although it may not be feasible to adopt non-suppression policies of wildfire management, the impacts of fire suppression must be understood before remedial measures can be taken or silvicultural methods that emulate fire are developed. Without consideration for the ecological role of fire in forest ecosystem management, problems related to ecological integrity and productivity may be encountered, and the recognition of these impacts and the development of means to counteract them is a crucial part of any forest ecosystem management. This paper will emphasize the effects of fire protection from the microsite, stand, landscape and genetic levels for various types of forest ecosystems in Canada.

Army Fire Research and Development

Class A Foam Evaluation

Submitted by: Samuel Duncan
Department of Army
Tank-Automotive Research
Development & Engineering Center
Fire Research and Development
Fort Belvoir, Virginia

Abstract:-

The Army Materiel Command (AMC), responding to procurement inquiries, requested information from the Army research community at Fort Belvoir about the performance of Class A firefighting foam.

In compliance with current Department of Defense policy, we sought non-government standards as guidance for our response to AMC and found that there were no performance standards for Class A firefighting foams. We determined that an appropriate response might include a program of performance evaluations of foams regarded as having met a level of environmental acceptance, such as the U.S. Department of Agriculture's Qualified Products List.

The evaluation was conducted using test procedures found in the NFPA project. The program received limited funding and the data is not considered conclusive. It clearly shows, however, the Class A firefighting foams improve the performance of water alone and that much more research is needed.

Quantitative Evaluation of Enhanced Water Fire Suppression

Submitted by: Bruce Edwards
Firetech Engineering Inc.
Vancouver, BC

Abstract:-

To use scarce water resources most effectively, firefighters must maximize the number of metres of wildfire that can be suppressed per litre of water, for a given fuel type, topography, and weather. This is done by optimizing the delivery system, method of application, and flow rate. As a step to achieving this, reproducible wood crib fires are being studied to quantify the effect of factors involved in suppression.

Large cribs, extrapolated from the UL 711 standard design (up to 40-A cribs), are being used so that practical suppression equipment can be used, thereby making the results relevant to field personnel.

Preliminary burns of eight "100-AB" (3600 lb) fuel cribs in 1992 confirmed the value of testing large fires and the feasibility of quantitative studies. These burns led to estimates of CFR (Critical Flow Rate) for straight streams of ALEF-A (Aspirated Low Expansion Class A Foam) of 80 gpm compared to 160 gpm for plain water. Foam solution was tested, and 100 psi fog was compared with 50 psi fog. Video clips of test burns, including a foam test on heavy logging equipment, form part of this presentation. Rationale for the experimental design is discussed.

Twelve crib fires this summer will indicate fire scaling in fuel cribs, which information will be used to size sixty "60-AB" fuel cribs and, given additional funding, twenty "100-AB" cribs. These will be attacked with plain water and several class A foam delivery systems, including Compressed Air Foam Systems (CAFS), using various methods of application. This procedure will quantitatively identify the most promising combinations. It is intended, if resources permit, to evaluate these combinations with fires in natural fuels.

Overview of Recent and Planned Studies on Fire Retardant Chemicals

Submitted by: Susan E. Finger
National Biological Survey
National Fisheries Contaminant Research Center
Columbia, Missouri

Abstract:-

Fire retardants and suppressants are used extensively for suppression and control of range and forest fires. Each year, fire control agencies utilize millions of gallons of these mixtures on a wide array of ecosystems. These chemicals are commonly applied to environmentally sensitive areas that may contain endangered, threatened, or economically significant plant and animal species. Relatively little information is available on the toxicity of these chemicals to aquatic and terrestrial life. Even less information is available on the community and ecosystem level effects.

The National Biological Survey, a newly formed research agency within the Department of Interior, is conducting studies to provide sound scientific and legally defensible information on the potential effects of these chemicals to aquatic and terrestrial resources. Specific objectives of these studies include (1) to evaluate the acute toxicity of a group of these chemicals to aquatic organisms under laboratory conditions, (2) to evaluate the toxicity of a group of these chemicals to terrestrial organisms under controlled conditions, and (3) to determine the ecological significance of application of these chemicals . Results from these studies will be summarized in presentations by scientists from the National Biological Survey.

International Wildland Fire Foam Specification and NFPA 298 - Foam Chemicals for Fire Control

Submitted by: Charles W. (Chuck) George
USDA Forest Service
National Wildfire Suppression Technology (NWST/ Unit)
Missoula, Montana

Abstract:-

In 1986 when the USDA Forest Service began using foam in its wildfire control program, products were tested and procured under a set of Interim Requirements. The requirements were not specific to foams but were common to all of the wildland fire chemicals: health and safety, stability, and corrosion.

In 1992 an International Foam Specification Workshop was held in Missoula, Montana. A list of the characteristics of foam concentrate, foam solution, and foam that may be desirable or cause for concern to any of the user agencies was compiled. These characteristics were incorporated into a draft "International Wildland Fire Foam Specification." This document was reviewed by representatives of firefighting agencies and chemical suppliers from the United States, Canada, France, and Australia. Comments were incorporated into a revised specification.

Test methods and performance requirements were specified where they were readily available. In other cases, a test method may be specified without performance requirements. In a few cases, even the test method must be developed. That project is ongoing.

The National Fire Protection Association (NFPA) developed a standard (NFPA 298) to cover wildland fire foams during the same time period. The Forest Service and Bureau of Land Management worked on the original document and on the revision of NFPA 298 which is nearly complete. While not identical, NFPA 298 is very similar to the International Specification.

Toxicity of Fire Retardant Chemicals to Aquatic Organisms

Submitted by: Steven J. Hamilton, Susan F. McDonald, Mark Galkowski, and Kevin J. Buhl, National Biological Survey
National Fisheries Contaminant Research Center
Yankton Field Research Station
Yankton, South Dakota

Abstract:-

Fire retardant and suppressant chemicals used extensively in North America are often applied in environmentally sensitive areas that may contain endangered, threatened, or economically important plant and animal species. We conducted laboratory acute toxicity tests in both hard and soft waters with five commonly used fire control chemicals (Fire-Trol LCG-R, Fire-Trol GRS-R, Phos-Chek D75-F, Phos-Chek WD-881, and Silv-Ex). Organisms used in the tests included two fish (rainbow trout and fathead minnow), two aquatic invertebrates (<u>Daphnia magna</u> and <u>Hyalella azteca</u>), and a green algae (<u>Selenastrum capricornutum</u>). In general, the green algae was substantially more sensitive to the three non-foam fire chemicals than the animals, and the <u>Daphnia</u> were the most sensitive test organism in exposures with foams. The two foams (Silv-Ex and Phos-Chek WD-881) had similar toxicity and were more toxic than the three non-foams. Water quality did not seem to modify the toxicity of the five fire chemicals in a consistent manner.

Efforts In Characterizing Wildland Fire Foams

Submitted by: Ceci Johnson
USDA Forest Service
National Wildfire Suppression Technology (NWST/ Unit)
Missoula, Montana

Abstract:-

The International Specification for Wildland Fire Foam contains a number of characteristics of interest to users of firefighting foam. A Foam Characterization Study was undertaken to provide the information necessary to transform the draft specification and characteristics list into a formal specification.

The information to be developed for each characteristic includes a suitable test method, performance of foams currently in use, and a range of acceptable performance. The performance information will be available to the end user to aid in product selection.

The characteristics fall into one of the following broad categories:

- Health, Safety, and Environment
- Corrosion and Materials Effects
- Physical/Chemical Properties
- Effectiveness
- Stability

Where suitable test methods are available most of the work is between 75 and 100 percent complete. Several of the tests that have not been completed, have appropriate test methods available, but the tests are costly to run. In other cases test methods had to be developed. That work is progressing.

Brief History of Class A Fire Control Foam In Canada

Submitted by: R.R. Lafferty
Fire Management Officer
MacMillan Bloedel Ltd.

Abstract:-

Class A foams were used in Europe in the 1930's but those products that we use today evolved from some special work done in eastern Canada in the early 1980's and northwestern Canada in the mid 1980's. Of course, considerable development work has been done on product and equipment since then.

Many industry and government people, in the United States and Canada, deserve credit for the high level of expertise that exists in the world today. Five years from now there will be more development to report due to the dedicated people in the business.

The new generation Class A fire control foam is unique because of its ability to perform well at 1.0% and 0.1% solution mix. Because of the low concentrations, it is used in fire bombing fixed wing and rotor wing aircraft. Class A foams are not bulky and some say they are inexpensive. They do suppress fires that plain water has little impact on. There is no doubt that Class A foam is an efficient fire suppressant.

In 1981, 1982, and 1983, Class A foams were 3 to 6%. In 1983, George Cowan and Eddie Cundasamy of Wormald International invented Silv-Ex Class A Foam. This new generation foam was concentrated and intended to be mixed at 1.0% to 0.1% solution.

Since 1984, several other companies have developed concentrated Class A foam and many millions of litres have been used. My talk gives a brief description of some of the activities that have led to the use of foam today.

Québec Environmental Activities on Fire Extinguishing Foams

Submitted by: Robert Langevin, Pierre-M. Marotte and Renaud Dostie
Ministère des Ressources naturelles du Québec
Direction de l'environnement forestier
Québec Natural Ressources Ministry
Forest Environment Directorate

Abstract:-

In the province of Québec, aerial applied forest fire extinguishing foams have been used since 1988. The Ministère des Ressources naturelles du Québec (MRN) is officially appointed to insure its safe use for the environment, in compliance with forest and environmental protection provincial laws. Its activities also include human health protection. Four products, Phos-Check WD 881^MD, Silv-Ex^MD, Forexpan^MD, and Firetrol 103^MD, are authorized for use by the Québec Environment and Wildlife Ministry.

Among the main achievements of the MRN was the publication, in 1991, of a "Fire Extinguishing Foams User's Guide," putting forward recommendations for workers and environmental protection during routine operations and accidental events, with Phos-Check WD 881, the only product used so far. According to these recommendations, workers on information sessions as well as operational headquarters inspection take place periodically. Equally important, is the thorough hazard evaluation of all four authorized foams realized in 1992.

In the meantime, the MRN has conducted five field studies to evaluate Phos-Check environmental impact and contamination. The effects of a spill on aquatic invertebrates living in a stream and foam phytotoxicity were studied. Waterbodies contamination by CL-215 or helicopter while bailing, and during regular firefighting operations with foam were investigated.

Terrestrial Vegetation Response to Silv-Ex Application

Submitted by: Diane L. Larson
National Biological Survey
Northern Prairie Wildlife Research Center
Jamestown, North Dakota

Abstract:-

During spring 1993, studies were conducted to evaluate the effects of a fire retardant foam, Silv-Ex, on the terrestrial vegetation bordering a wetland ecosystem. A grid, of 30 blocks of 0.4 hectare each, was delineated in a quarter section of unbroken prairie sod at Woodworth Field Station, Stutsman County, North Dakota. Each of four treatments was assigned randomly to six 10 m x 10 m blocks (one centered within each 0.4 hectare block) within the grid. Treatments included (1) Silv-Ex application, (2) burn plus Silv-Ex, (3) burn only, and (4) no manipulation. A 0.5% Silv-Ex solution was applied at the rate of 50 gallons per 10 m x 10 m plot, resulting in approximately 0.25 gallons of Silv-Ex on each plot. Expansion was estimated to be 1:10. We examined variation among treatments in growth rate, biomass accumulation, herbivory and number of plant species per plot.

Silv-Ex application had no effect on biomass accumulation, whether or not the plot had been burned. The foam did depress the number of species per plot; this effect was enhanced by burning. Bluegrass growth rate was not affected by Silv-Ex. Herbivory, although slight, varied among treatments. In the absence of fire, both broad-leaved and graminoid species experienced considerable browning after foam application.

The Use of Wildland Fire Foam in the Province of Québec

Submitted by: François Lefebvre
Société de protection des forêts contre le feu
Sainte-Foy, Québec

Abstract:-

The objective to minimize the costs and losses due to forest fires has pushed the Québec organization, like every other agency involved in forest fire protection, to look for new tools to fulfill its mandate. Since 1985 the province of Québec has been involved in the use of wildland fire foam. The high expectations from the beginning have been replaced by major concerns: Is the use of wildland fire foam worth it? We have three major concerns: Is the use of wildland fire foam economically viable; does our knowledge about these products allow us to use them the proper way; what are the consequences on the environment when these products are used? When we tried to find some answers in existing literature,

we discovered that very few quantitative results exist. In 1993 we initiated a small experiment. Two objectives were established: What effect does wildland fire foam have on the fuel moisture compared to the simple use of water? What effect does wildland fire foam have on extremely hot fuel?

Preliminary Investigation of the Fire Extinguishment Effectiveness of Compressed Air Foam

Submitted by: Daniel Madrzykowski
Building & Fire Research Laboratory
National Institute of Standards & Technology
Technology Administration
U.S. Department of Commerce
Gaithersburg, Maryland

Abstract:-

A study was conducted to investigate the extinguishment effectiveness of compressed air foam (CAF) on Class A fires as a means to assess the feasibility of a self-contained, CAF sprinkler system for residential fire protection. Two types of fire tests were conducted: (1) fire extinguishment effectiveness tests and, (2) sprinklered compartment fire suppression tests.

The fire extinguishment effectiveness tests utilized wall configuration wood cribs, with overall dimensions of 0.61 m x 1.22 m in height. This crib configuration exhibited a steady-state heat release rate of approximately 250 kW. After the crib was ignited and allowed to reach full involvement, manual extinguishment was initiated by applying the extinguishing agent in a predetermined pattern over the burning fuel. When the flames were suppressed, the operator would look for smoldering combustion (hot spots) and apply more agent only to those areas. This technique was used to minimize the amount of agent used to extinguish the fire. The CAF and plain water were applied to the fuels at the same mass flow rate for each comparative case. Based on time to extinguishment, CAF exhibited an effectiveness similar to water when suppressing the wood crib fires. The sprinklered compartment fire suppression tests required the agent, delivered from a sprinkler, to suppress a wood crib fire in a 2.4 m x 2.4 m x 2.4 m compartment. The wood cribs had external dimensions of 0.25 m x 0.25 m x 0.30 m in height and a calculated peak heat release rate of approximately 50 kW. The crib was allowed to become fully involved prior to manual activation of the sprinkler system.

At a spray application rate of 2.9 mm/min. (0.07 gpm/ft^2), CAF was found to be no more effective than water in suppressing the fire. A discussion of the limitations of the results from this study and needs for future research are included.

CAFS Power Systems and Proportioning Equipment Performance

Submitted by: Dan W. McKenzie
Mechanical Engineer, USDA Forest Service
Technology & Development Center
San Dimas, California

Abstract:-

CAFS Power Systems

In designing and fabricating power systems for Compressed Air Foam Systems (CAFS) the following guidelines should be followed:

- With the CAFS in place, there should be no deterioration of the water handling capability or reliability of the fire engine.
- With the CAFS in operation the fire engine should be able to make a running attack.
- Operation of the fire engine equipped with CAFS should be easy and simple (user friendly).

There are five general arrangements now in use to power CAFS. They are:

1. Two auxiliary engines, one driving the centrifugal water pump and the other driving the air compressor.
2. Single auxiliary engine mechanically driving both the centrifugal water pump and the air compressor.

3. Fire truck engine driving the centrifugal water pump and the air compressor by direct mechanical drives.

4. Fire truck engine driving the centrifugal water pump and the air compressor through a load sense hydraulic drive system.

5. Fire truck engine driving the centrifugal water pump and the air compressor by a direct mechanical drive and driving the fire truck by a constant engine speed automatic transmission.

Drive systems 1, 2, 4, and 5 will allow the fire truck to make a running attack. When using drive arrangement 3, the CAFS fire truck cannot make a running attack. If running attack is not required or not important, directly mechanically driving the water pump and the air compressor by the fire truck engine is a good way to drive the CAFS equipment and is mechanically equivalent to a single auxiliary engine CAFS drive system.

Each of the components of a CAFS (centrifugal water pump, air compressor, foam concentrate proportioning system, and control and instrument system) must be sized, driven, and controlled to produce a well operating and reliable CAFS unit. In recent years as the use of CAFS has increased, several good "rules-of-thumb" have been identified. They are:

1. A centrifugal water pump should be used in a CAFS unit with water pressure controlled by pump rpm and, if possible, stand alone in operation.

2. The air compressor used in a CAFS should be a modulating-type with pressure adjustment at the panel and, if possible, stand alone in operation. When in CAFS operation the air pressure should be capable of being controlled by water pressure.

3. As a general rule the centrifugal water pump selected should have a rating in gpm of at least twice the air compressor rating in cfm.

4. In the operation of a CAFS unit, static water pressure and static air pressure should be equal and air pressure should be automatically controlled by water pressure.

5. Water flow and air flow should be adjustable and controlled by variable orifices (ball valves) or other equal controls.

6. At a minimum; water, air, and mix point pressure gauges, plus water and air flowmeters should be available to the operator. Also desirable is an indication that foam concentrate is flowing.

7. An automatic regulating proportioning system injecting foam concentrate into the discharge side of the pump should be used.

8. Open CAFS nozzles very slowly. If they are opened quickly, the nozzle reaction can be quite intense for a short time.

By following the above "rules-of-thumb", satisfactory results are currently being obtained in the design, manufacture, and operation of CAFS units. When procuring CAFS equipment, a person knowledgeable in CAFS equipment should be used in the development of the specifications and should assist in the contract administration, inspection, and test. Crew leaders and crew members should also receive special training in CAFS operation.

Foam Proportioning Equipment

There are two basic types of foam concentrate proportioning systems:

1. Manually regulated proportioning systems.
2. Automatic regulating proportioning systems.

Manually regulated proportioning systems include:

Batch mixing
Suction-side proportioner
In-line eductor
Variable flow Bypass eductor
Around-the-pump proportioner
Direct injection, manually regulated.

Automatic regulating proportioning systems include:

- Balanced pressure venturi systems
  - a. Pump systems
  - b. Bladder tank systems
- Water-motor meter proportioner
- Direct injection, automatic regulating proportioner

All manually regulated proportioning systems have significant disadvantages when used in wildland fire applications. In general, manually regulated proportioning systems do have one desirable advantage—low initial cost. However, manually regulated proportioning systems (other than batch mixing) have the potential of using more foam concentrate than necessary, negating their initial low cost advantage and, in reality, becoming the most costly proportioning system. Thus, manually regulated proportioning systems should be avoided, or when used, used with caution in wildfire suppression operations.

Due to the many shortcomings of the manually proportioning systems, automatic regulating proportioning systems have been designed to reduce these limitations. Specifically, the automatic regulating proportioning systems are designed to remain proportional over a wide range of flows. They are not affected by changes in engine pressure, changes in hose length and size, or changes in nozzle adjustments, size, or elevation and generally inject the foam concentrate into the discharge side of the pump. The use of automatic regulating proportioning systems injection into the discharge side of the pump should be encouraged.

To encourage the use of automatic regulating proportioning systems injecting into the discharge side of the pump, automatic regulating proportioning systems should be formally tested and test results appropriately disseminated. Proportioning systems installed on engines should also be tested to insure that they are operating properly as installed.

Toxicity of Fire Suppressant Foams to the Aquatic Community

Submitted by: Barry C. Poulton and Susan E. Finger
National Biological Survey
National Fisheries Contaminant Research Center
Columbia, Missouri

Abstract:-

During spring 1993, two field exposures were conducted to determine the effects of fire suppressant foams (Silv-Ex and Phos-Chek WD-881) on aquatic life. Exposure #1 was performed in Fish Lake at the Woodworth Field Station, Stutsman County, North Dakota. Exposure #2 was performed in an experimental pond at the National Fisheries Contaminant Research Center in Columbia, Missouri. Twenty-four limnocorrals were designed to enclose approximately 2500 L of water so that chemical dosage could be applied without leakage. Within each limnocorral, fathead minnows and water boatmen (Cenocorixa) were placed in separate environmental chambers to assess effects on single species. Community effects were evaluated by examining aquatic macroinvertebrates that had colonized artificial substrates trays in each limnocorral.

Similar to observations in the laboratory, field studies showed that Silv-Ex was more toxic to aquatic organisms than was Phos-Chek WD-881. Although, in these field studies, no appreciable mortality occurred in fathead minnows exposed to the lowest observed effect concentration (calculated from laboratory data), complete mortality did occur at concentrations approximating the LC50. Analysis of information on macro-invertebrate community responses to these chemicals is in progress.

Toxicity, Health, and Safety of Wildland Fire Foam

Submitted by: Robert J. Sabol
STILLMEADOW, Inc.
Sugar Land, Texas

The paper includes an overview of the history of mammalian testing and specifically how this type of testing was adapted to the needs of the U.S. Forest Service. Current testing requirements are reviewed and the estimated cost of the evaluation of a sample in the primary areas of acute toxicology testing are presented. A consideration of possible future testing requirements in the areas of inhalation, skin sensitization, and in vitro options are also explored.

Indirect Tactical Applications with Foam

Submitted by: Paul Schlobohm
Bureau of Land Management
National Interagency Fire Center
Boise, Idaho

Abstract:-

Class A foam is a short-lived foam relative to other types of foam. Rapid drainage and unstable structure are ideal for direct suppression activities such as flame knockdown and mop-up. Why then, is foam so successful for indirect applications such as fireline construction and resource protection?

The answer is foam's active ingredient—water. Water is a powerful medium for slowing the spread of fire, but, unaltered, water is not efficient. Foam is a way of restructuring water to a form that best fits the task. A variety of foam generating equipment has provided an array of options for effectively placing water on exposures. The use of foam has enabled us to put water in place as a barrier like we have never done before. Successful applications depend on the appropriate foam type, complete coverage, and wetting of the exposure timed to match the time of flame impingement.

The Use of Foaming Agents in Forest Firefighting in Spain

Submitted by: Ricardo Velez
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Ministry of Agriculture
Gran Via San Francisco 4
28005 Madrid, Spain

Abstract:-

A historical overview on the aerial means used for foam application is made. It is specially described the technical requirements for the concentrate. It is also described which is the current "state-of-the-art" regarding foam application for the "when and how" questions. Finally future developments in that field are discussed.

Included is a historical overview, characteristics of the concentrate, current situation, future developments, and aerial means operating in Spain for Forest Firefighting in 1994.

It was in 1987 when foaming agents appeared in the forest fires scenario to improve water drops efficiency. At that time, only 3 of a fleet of 12 Canadair CL-215 aircraft were equipped with foam injection systems. Later, taking advantage of revamping to turbo-engines in Canada, they were progressively equipped with the above mentioned system up to a total of nine in 1994 operative with foam.

In a similar way, helicopters began to be used in extinction jobs, not only those exclusively prepared for that purpose with fixed tanks, but also those for which the main commitment is to transport firefighters at the operation scenario. Once there, the pilot attaches the bucket and starts its fight against the wildfire.

In 1993, approximately 50 percent of the helicopter fleet involved in forest firefighting used foam. Foam was also used by a DC-6 that operated from Almeria (South of Spain) with very satisfactory results.

The average use of foam concentrates for the last four years has been approximately 50,000 litres per year.

The essential requirements that a foam concentrate must have for use in Spain are:

1. They must be highly concentrated so they can be used with successful results at a lower concentration than 1 percent.

2. Foaming agents must be corrosion inhibited for their use in aerial means—specially in

helicopters with fixed tanks where the tail rotor can be corroded when wetted in the drop.

3. Acceptance from recognized bodies, like Canadair, Inc., that foam concentrate can be loaded, transported, and handled safely by aerial means (a very high ignition point, etc.).

4. Studies from well known laboratories about the effects of foam use on the ground on aquatic flora and fauna.

All these points are included in the technical requirements described in our respective specification.

Guidelines for foam use include foam concentrations, foam percentages, and logistics.

Our operational percentages of foaming agent on ground use in either direct or indirect attack are 1 percent concentrations. For mop-up operations, where foam is not required but a good wetting effect is needed, the percent is 0.1.

The trend is toward the design of equipment that allow a variable injection of foam concentrate according to the water flow. This compact equipment should be placed in a truck and essentially would include:

1. Flow-meter

2. Microprocessor

3. High-pressure volumetric pump (variable flow rate)

4. Accessories (check valve, etc.)

We expect to test some equipment this year, during the summer, in a real fire situation.

Fixed-wing aircraft used by ICONA in 1993 included 21 Canadair CL 215, 5 CANSO PBY, and 1 DC-6. Twenty helicopters were equipped with buckets, 5 used fixed tanks, and 4 were used for surveillance.

Toxicity of Fire Retardant Chemicals to Wildlife Species

Submitted by: Nimish B. Vyas, James W. Spann, W. Nelson Beyer, and Elwood F. Hill
National Biological Survey
Patuxent Wildlife Research Center
Laurel, Maryland

Abstract:-

Under laboratory conditions, acute single-dose oral toxicity tests (LD50) were conducted with three fire retardant chemicals (Fire-Trol GTS-R, Phos-Chek D75-F, and Fire-Trol LCG-R) and two fire suppressant foams (Silv-Ex and Phos-Chek WD-881) to determine effects on adult northern bobwhite, American kestrel, red-winged blackbird, and white-footed mouse. In addition, earthworms were exposed (LC50) for 14 days in treated soil.

In general, no toxic responses were evident. For northern bobwhite, the LD50 for all five chemicals was >2000 mg a.i./kg of body mass. American kestrels regurgitated all chemicals except Silv-Ex; LD50s all exceeded 2000 mg/kg. The LD50 for red-winged blackbird was also >2000 mg/kg for all chemicals except Fire-Trol GTS-R which is currently undergoing further testing. In addition, the LD50 for white-footed mouse was >2000 mg/kg for Phos-chek D75-F. The 14-day LC50 for earthworms was >1000 ppm for all chemicals. Therefore, we concluded that these retardants and foams do not pose an acute hazard to adult birds, mammals, or earthworms. However, ecological studies to evaluate the potential effects of these formulations on vertebrate behavior and population dynamics are in progress.