

# **HUMAN HEALTH RISK ASSESSMENT OF WILDLAND FIRE-FIGHTING CHEMICALS: WATER ENHANCERS**

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**EXECUTIVE SUMMARY**  
**HEALTH RISK ASSESSMENT OF WILDLAND FIRE-FIGHTING CHEMICALS:**  
**WATER ENHANCERS**  
**October 2020**

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 water enhancers examined their potential impacts on fire-fighters and members of the public. Typical and maximum exposures from planned activities were considered, as well as an accidental drench of an individual in the path of an aerial drop.

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 health and the human environment, including aircraft noise, cumulative impacts, physical injury, and other direct or indirect effects. Environmental assessments or environmental impact statements pursuant to the *National Environmental Policy Act* would consider chemical toxicity, as well as these other potential types of effects, to make management decisions.

Each water enhancer product used in wildland fire-fighting is a mixture of individual chemicals. The product is supplied as a concentrate, in either a liquid or powder form, which is then diluted with water to produce the mixture that is applied during fire-fighting operations. The risk assessment process for a product had a two-part approach: (1) toxicity data on the whole product were considered, to account for any effects due to the product being a mixture (synergism or antagonism); and (2) each and every ingredient in the product formulations was screened, and risk from any ingredient with higher toxicity was separately quantified.

The results presented in this risk assessment depend on a number of factors, including the availability of relevant scientific information, standard risk assessment practices, exposure assumptions, and toxicity dose-response assumptions. Whenever possible, this risk assessment integrated chemical-specific scientific information on toxicity endpoints. The approaches used to address these factors introduce minor to significant amounts of uncertainty into the risk assessment's conclusions; this assessment identifies the types of uncertainty affecting this analysis and estimates the degree to which they may affect the conclusions reached. Overall, when assumptions were required, a conservative approach was taken, to provide risk results that are protective of human health.

**Summary of Estimated Risks to Human Health from Water Enhancers**

- For typical exposures, all products and individual ingredients within them were predicted to pose negligible risk to fire-fighting personnel from the water enhancer products.
- In the maximum scenarios:
  - The hazard quotients for two products (the uncolored and colored variant of the same product) exceeded one, indicating a risk for male and female airtanker base

personnel mixing FireIce 561 and Fire Ice 561 Cool Blue-F. Forest Service policy does not allow application of water enhancers from large multi-engine airtankers, but this scenario is assessed for the information of those agencies whose policy permits this use.

- One ingredient used as a pH buffer in one product was predicted to pose a risk for airtanker base personnel mixing the product. This ingredient was assessed based on its initial composition as an ingredient input to the product's formulation. It is likely that the final product contains a significantly smaller amount of this ingredient when it performs its role as a chemical buffer, resulting in no expectation that an actual risk is present.
- No risks were predicted for adult and child members of the public cleaning a structure that had been treated with any water enhancer.
- In the accidental drench scenario, no risks were predicted for workers or members of the public from any water enhancer.
- Risks are expected to generally be negligible for
  - rehabilitation team members
  - individuals who could re-enter areas to which a water enhancer has been applied, such as hikers, researchers, hunters, biologists, or children playing
  - dermal exposure from harvesting mushrooms or berries from wildlands after vegetative regrowth has occurred, in areas that were treated with water enhancers
  - handling dogs or other domestic animals whose fur contains residues as a result of exposure to vegetation in treated areas
- Individuals are advised against consuming vegetables from home gardens to which a water enhancer may have been applied, or from areas in wildlands where residues are apparent.

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## ***Acronyms and Abbreviations***

EPA	Environmental Protection Agency
kg	kilogram
L	liter
LD <sub>50</sub>	median lethal dose
LOAEL	lowest observed adverse effect level
m <sup>3</sup>	cubic meter
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m <sup>3</sup>	milligrams per cubic meter
NOAEL	no observed adverse effect level
ppm	parts per million
QPL	Qualified Products List
RfD	reference dose
U.S.	United States

# HUMAN HEALTH RISK ASSESSMENT OF WILDLAND FIRE-FIGHTING CHEMICALS: WATER ENHANCERS

## 1.0 INTRODUCTION

The U.S. Forest Service uses a variety of chemicals to aid in the suppression of fire in wildlands, including long-term retardants, Class A foams, and water enhancers. The potential human health impacts of the products were first assessed in a programmatic risk assessment prepared in 1994. The risk assessment has been periodically updated to include new products and assessment approaches. The current format of these reports provides a structure for maintaining the product-specific risk assessments that eases reference, access, and organization of the most current information for each product.

This risk assessment analyzes the human health risks of using water enhancers in wildland fire-fighting. A companion report evaluates the ecological risks from water enhancer use. Separate risk assessments address human health and ecological risks from long-term retardants and Class A foams.

The risk assessment methodology that was employed for assessing the health risks from water enhancers is detailed in the main section of this document. The main document also includes a concise discussion and summary of risk conclusions for the products in use. Product-specific analyses are separate attachments to this document, allowing for assessments of newly qualified water enhancer products to be developed and attached, without revision of the entire report and all contents. Updates within this main document would be contained in any future revision to the “Current Risk Summary” subsection of Section 4.

This report is organized into 5 major sections. Section 1.0 provides an introduction, background information, and an overview of the analysis approach. Section 2.0 presents the hazard assessment methodology. Section 3.0 provides the exposure assessment methodology. Section 4.0 presents the risk characterization methodology and summary of estimated risks. Section 5.0 lists the references cited throughout this report. The attachments present the product-specific detailed risk assessments.

## 1.1 Background: Fire-Fighting Chemicals

The information in the following paragraphs was derived from the Forest Service's Wildland Fire Chemicals Systems information web site (USFS 2020):

- *Long-term retardants*, commonly referred to as retardants, are applied from aerial or ground equipment. The red liquids dropped from aircraft, often viewed in media coverage of wildland fire-fighting activities, are retardants. These products, which are primarily the same salts found in agricultural fertilizers, are supplied as either wet or dry concentrates. They are mixed with water in a prescribed ratio and applied to a target area just ahead of a fire (during

wildland firefighting) or prior to a fire (during prescribed fire operations). While the water contained in the mixed product aids in firefighting, its primary purpose is to aid in accurately delivering the product to the fire. They continue to be effective after the water in the mixture has evaporated, as the fertilizer salt residue slows the spread and reduces the intensity of fire.

- *Class A foams* are supplied as liquid concentrates similar to liquid dishwashing products that are mixed with water and then aerated to produce foam. They are applied from aerial or ground equipment directly to the fire area to slow or stop combustion. Foam bubbles and their components (water and the concentrated product in it) interact with fuel surfaces in several ways. The fuels may absorb the moisture as it drains out of the foam mixture, which makes them less susceptible to combustion, and may be protected from wind, heat, and flame by foam coating the fuel's surface. Depending on the desired outcome, a wide range of foam characteristics can be prepared from the same concentrate by changing the mix ratio and adjusting the foam generation and application method used. Higher amounts of concentrate and aeration in the foam solution produce drier, slow draining foam for vertical surface protection. Moderate amounts produce wetting, fast draining foam for vegetation (horizontal surface) application. Low amounts can be used to make "wet water" that has enhanced penetration for mop up.
- *Water enhancers*, commonly referred to as gels, are supplied as liquid or dry concentrates that contain thickeners and other ingredients that, when mixed with water, improve aerial application, minimize drift, and aid in adherence to fuels. Water enhancers may be applied from ground or aerial application equipment. These products may be used in structure protection within the wildland interface or on wildland fuels. The effectiveness of water enhancers depends on the water content of the gels and, once they dry out, they are no longer effective.

Class A foams and water enhancers increase the inherent ability of water to suppress fire, while retardants leave a dried residue after the water evaporates that helps to protect the fuel from burning.

Fire-fighting chemicals may be dropped from fixed-wing airplanes ("airtankers") or helicopters, or applied by ground crews from fire engines or using portable equipment; the application methods approved for each product are listed on the current Qualified Products List (QPL), which can be found online at [www.fs.fed.us/rm/fire/wfcs/index.htm#qpl](http://www.fs.fed.us/rm/fire/wfcs/index.htm#qpl).

## 1.2 Overview of Analysis

The purpose of this assessment is to estimate the risks to the health of workers and the public as a result of the use of water enhancers in wildland fire-fighting. This human health risk assessment looks only at the biological risks of the water enhancers, should they be used. It does not evaluate alternatives to their use, nor does it discuss factors affecting management decisions on whether chemicals should be used in a particular situation.

This human health risk assessment employs the three principal analytical elements that the National Research Council (1983) described and the U.S. Environmental Protection Agency

(EPA) (1989, 2000, 2012a) affirmed as necessary for characterizing the potential adverse health effects of human exposures to existing or introduced hazards in the environment: hazard assessment, exposure assessment, and risk characterization.

### 1.2.1 Hazard Assessment

Hazard assessment requires gathering information to determine the toxic properties of each chemical and its dose-response relationship. Sometimes this element of the health risk assessment process is divided into two separate steps: hazard identification and dose-response assessment:

1. Hazard identification determines whether exposure to a stressor can cause an increase in the incidence of specific adverse health effects and whether the adverse health effect is likely to occur in humans. That is, it answers the question “What health problems does the chemical cause?”
2. Dose-response assessment describes how the likelihood and severity of adverse health effects are related to the amount of exposure to a chemical (the “dose”). It answers the question “What are the health effects at different levels of exposure?”

Human hazard levels are derived primarily from the results of laboratory studies on animals. The goal of this hazard assessment is to identify acceptable doses for noncarcinogens, and identify the cancer potency (a factor that relates dose to cancer risk) of potential carcinogens.

In this risk assessment, the toxicity of each product formulation as a whole was assessed, as well as the toxicity of some individual ingredients in the product formulations, according to criteria described in Section 2.3.2.

### 1.2.2 Exposure Assessment

Exposure assessment involves estimating doses to persons potentially exposed to the water enhancers. It answers the question “How much of the chemical are people exposed to?” In this exposure assessment of the water enhancers, dose estimates were made for typical, maximum, and accidental exposures for firefighting personnel and members of the public. These exposures are defined as follows:

- *Typical*: Typical exposure reflects the average dose an individual may receive if all exposure conditions are met. Typical exposure assumptions include the average amount of a chemical to which an individual may be exposed in a day, the average number of days worked throughout their fire-fighting career, the amount of residue that a homeowner may encounter while cleaning it off of their house, the average length of time elapsed until showering or changing clothes, and other similar assumptions.
- *Maximum*: Maximum exposure defines the upper bound of credible doses that an individual may receive if all exposure conditions are met. Maximum exposure assumptions include the estimated upper bounds on the amount of a chemical to which an individual may be exposed in a day, the number of days worked throughout their fire-fighting career, the amount of



residue that a homeowner may encounter while cleaning it off of their house, the length of time elapsed until showering or changing clothes, and other similar assumptions.

- *Accidental:* The possibility of error exists with all human activities. Therefore, it is possible that during fire-fighting activities, an individual fire-fighter, other worker, or member of the public could be in the path of an aerial drop, resulting in an accidental drench. This accident scenario was evaluated for potential health effects to all individuals.

Exposure scenarios are described in detail in Section 3.0. It is important to note that these scenarios estimate risks from clearly defined types of exposure. If all the assumptions in an exposure scenario are not met, the dose will differ from that estimated here, or may not occur at all.

### 1.2.3 Risk Characterization

Risk characterization presents the results of the risk assessment in terms of the nature, and presence or absence, of risks. Risk characterization answers the question “What is the risk of health effects in the exposed population?” This step compares the hazard information with the dose estimates to predict the potential for health effects to individuals under the conditions of exposure. The risk characterization also identifies uncertainties (such as data gaps where scientific studies are unavailable) that may affect the magnitude of the estimated risks.

## 2.0 HAZARD ASSESSMENT

This section presents the approach for conducting the hazard assessment of the water enhancers—a review of available toxicological information on the potential human health hazards associated with the chemical formulations and individual ingredients used by the Forest Service. Section 2.1 provides background information to familiarize the reader with the terminology and technical information in this hazard assessment. Section 2.2 describes the hazard assessment methodology. Section 2.3 summarizes the approach for identification and development of the toxicity values used in this risk assessment. Section 2.4 describes the hazard assessment data gaps that affect the ability to quantify risks from these products and their ingredients.

### 2.1 Background Information

Because of the limitations on testing in humans, effects in non-human systems, primarily animals, provide the basis for an informed judgment as to whether an adverse impact is correlated with a particular exposure. Animal toxicity test results may be supplemented by information on a chemical's effects on humans, such as the results of dermatologic or exposure testing in humans, and occasional studies of low-level dosing of human volunteers by oral or other routes.

Toxicity tests in laboratory animals are designed to identify specific toxic endpoints (effects of concern), such as lethality or cancer, and the doses associated with such effects. Studies vary according to the test species used, the endpoint, test duration, route of administration, and dose levels. The dosing schedule, number of test groups, and number of animals per group also vary from one test to another, but the tests are generally designed to demonstrate whether a causal relationship exists between administered doses and any observed effects.

#### 2.1.1 Duration of Tests

The duration of toxicity tests ranges from single-dose (acute) or short-term (subacute) tests, through longer subchronic studies, to chronic studies that may last up to the lifetime of an animal. Acute toxicity studies involve administering a chemical to each member of a test group, either in a single dose or in a series of doses over a period less than 24 hours. Subacute, subchronic, and chronic studies are used to determine the effects of multiple doses. Subacute toxicity studies involve repeated exposure to a chemical for one month or less. Subchronic toxicity studies generally last from one to three months, and chronic studies last for more than three months.

Acute studies are used primarily to determine doses that are immediately lethal, which results in limited utility in an assessment of long-term or repeated low-level human exposures. Acute and subacute toxicity studies include dermal irritation tests, dermal sensitization tests, eye irritation tests, and inhalation exposure or daily oral dosing of laboratory animals for up to one month to further define effects from limited exposures.

Longer term studies are designed to characterize the dose-response relationship resulting from repeated exposure to a compound. All other things being equal, the greater the duration of the study, the more reliable will be the resulting value for estimating the effects of subchronic or chronic exposures in humans. Adverse effects in laboratory tests may include overt clinical signs of toxicity, reduced food consumption, abnormal body weight change, abnormal clinical hematology or chemistry, or visible or microscopic abnormalities in the tissue of the test organism. Chronic studies in rats or mice that continue for longer periods of time, usually about two years, may also be used to assess the carcinogenic potential of a chemical.

### **2.1.2 Routes of Exposure**

For assessing hazards from the water enhancers, the routes of administration in laboratory tests that reflect the likely types of exposures to humans include dermal (applied to the skin), inhalation (through exposure to vapors or aerosol particles), and oral by dietary (in food or water) or gavage (forced into the stomach through tubing). Selection of the route of administration of a particular test material is based on the probable route of human exposure.

### **2.1.3 Units**

A dose is expressed as milligrams of a chemical per kilogram of body weight (mg/kg) of the test animal, in parts per million (ppm) in the animal's diet, in milligrams per liter (mg/L) in the water that it drinks, or milligrams per cubic meter (mg/m<sup>3</sup>) in the air that the animal breathes. In chronic studies, the test substance is generally administered in the diet at specified amounts in parts per million (mg of chemical per kg of food). The known weight of the animal over the test period and its food intake rate are used to convert parts per million in the diet to milligrams of a chemical per kilogram of body weight per day (mg/kg/day) for extrapolation to humans. In most chronic toxicity studies, at least two dosing levels are used, in addition to a zero-dose, or control group. In general, the control group receives only the vehicle (for example, water or saline) used in administering the test material. In a dietary study, the animal's feed would serve as the vehicle.

### **2.1.4 Toxicity Endpoints**

In acute toxicity studies, the endpoint of interest is often the median lethal dose (LD<sub>50</sub>), which is the single dose that is calculated to be lethal to 50 percent of the test animals.

For examination of non-lethal, noncarcinogenic endpoints, toxicity testing can be used to estimate threshold exposure levels. The threshold level is the dose level at which a significant proportion of the test animals first exhibit the toxic effect. The threshold dose will vary among tested species and among individuals within species. Examples of toxic effects include pathologic injury to body tissue; a body dysfunction, such as respiratory failure; or another toxic endpoint, such as developmental defects in an embryo. It is not possible to determine threshold dose levels precisely; however, the no-observed-adverse-effect level (NOAEL) indicates the dose at which there is no statistically or biologically significant increase in the frequency or severity of an adverse effect in individuals in an exposed group, when compared with individuals in an appropriate control group. The next higher dose level in the study is the lowest-observed-

adverse-effect level (LOAEL), at which adverse effects are observed. The true threshold dose level for the particular animal species in a study lies between the NOAEL and the LOAEL. If a chemical produces effects at the lowest dose tested in a study, the NOAEL must be at some lower dose. If the chemical produces no effects, even at the highest dose tested, the NOAEL is equal to or greater than the highest dose.

Carcinogenicity studies are used to determine the potential for a compound to cause malignant (cancerous) or benign (noncancerous) tumors when administered over an animal's lifetime. Several dose levels are used, with the highest set at the maximum tolerated dose, as established from preliminary studies. A control group is administered the vehicle (the liquid or food with which the test chemical is given) alone. Because tumors may arise in test animals for reasons unrelated to administration of the test compound, statistical analyses are applied to the tumor incidence results to determine the significance of observed results. Amdur et al. (1991) listed four types of responses that have generally been accepted as evidence of compound-induced tumors:

- The presence of types of tumors not seen in controls.
- An increase in the incidence (compared to controls) of the tumor types that also occur in controls.
- The development of tumors earlier than in controls.
- An increased multiplicity of tumors.

Some chemicals that elicit one or more of these responses may not be primary carcinogens (that is, tumor-inducers on their own), but may be enhancers or promoters. However, a carcinogenicity evaluation remains appropriate, because they may contribute to an increase in cancer incidence. EPA's guidelines for carcinogen risk assessment (EPA 2005) list the following considerations for judging whether scientific studies indicate that a substance may cause a cancerous response: (1) consistency of the observed association, (2) strength of the observed association, (3) specificity for the observed association, (4) temporal relationship of the observed association, (5) exposure-response relationship, (6) biological plausibility, (7) coherence among lines of evidence, (8) experimental evidence from human populations, and (9) insights from structurally similar chemicals and modes of action (analogy).

For chemicals that are characterized as known or likely to be carcinogenic to humans, the dose-specific tumor incidence data are used to calculate a cancer slope factor, which represents the probability that a 1-mg/kg/day chronic dose of the agent will result in formation of a tumor, and is expressed as a probability, in units of "per mg/kg/day" or  $(\text{mg/kg/day})^{-1}$ . The approach to applying a slope factor may vary on a chemical-by-chemical basis, depending on the factors described above and also the level of exposure under consideration.

## 2.2 Hazard Assessment Methodology

The goal of the hazard analysis is to determine toxicity levels with which to quantify risk. There are two types of toxicity endpoints: noncarcinogenic effects and carcinogenic effects.

For noncarcinogenic effects, it is generally assumed that there is a threshold level, and that doses lower than this threshold can be tolerated with little potential for adverse health effects. The U.S. EPA has determined threshold doses for many chemicals, and refers to these as reference doses (RfDs). The RfD is an estimate of the highest possible daily dose of a chemical that will pose no appreciable risk of deleterious effects to a human during his or her lifetime. The uncertainty of the estimate usually spans about one order of magnitude (EPA 2002). The RfD is calculated using the lowest NOAEL from the species and study most relevant to humans, or the most sensitive species (the species that exhibited the lowest NOAEL overall). This NOAEL is divided by an uncertainty factor (usually 100) consisting of a factor of 10 to allow for the variation of response within the human population and a factor of 10 to allow for extrapolation to humans. Additional uncertainty factors may be applied to account for extrapolation from a shorter term study, overall inadequacy of data, or failure to determine a no-effect level. RfDs are expressed in units of mg/kg/day. EPA lists RfDs in its Integrated Risk Information System, a chemical risk database (EPA 2012b). RfDs can also be calculated using the steps outlined in EPA's methodology, if none has been developed by EPA. RfDs are analogous to the acceptable daily intake levels identified by groups such as the World Health Organization.

For compounds that are known or likely human carcinogens, cancer slope factors that have been calculated by EPA or other appropriate sources are identified for use in this risk assessment.

## 2.3 Toxicity Data and Estimation of Reference Doses

### 2.3.1 Formulations

For many chemicals, including the majority of those found in the fire-fighting products and the formulations themselves, long-term study data for estimating chronic RfDs are not available. Layton et al. (1987) developed a methodology for deriving acceptable daily intake levels for noncarcinogenic compounds for which chronic toxicity data are unavailable. This methodology uses acute toxicity data, specifically, LD<sub>50</sub>s. Acute and chronic toxicity values for many chemicals were correlated to identify a factor that allowed a reasonable estimate of a chronic NOAEL based on an LD<sub>50</sub>. The LD<sub>50</sub> is multiplied by this factor, which ranges from 0.00005 to 0.001, to obtain an estimate of the chronic NOAEL. This is the methodology on which the hazard assessment for the fire-fighting product formulations is based, because only acute toxicity data are available for these mixtures. In addition, Layton et al. (1987) summarized research that identified a factor of 5 that distinguished NOAELs in subchronic studies from NOAELs in chronic studies. Because the exposures evaluated in this risk assessment are predicted to occur at most 120 days per year (airtanker base personnel), this additional factor was also used in estimating the RfDs. The estimated NOAEL was then divided by an uncertainty factor of 100, to account for the uncertainty associated with interspecies extrapolation from laboratory animals to humans, and interindividual variation in sensitivity among humans. The estimated RfD was determined as follows:

$$RfD \text{ (mg / kg / day)} = \frac{LD_{50} \text{ (mg / kg)} \times 0.001 \times 5}{100}$$

This calculation was applied to the acute toxicity data for each of the products assessed, to provide an estimate of an acceptable exposure level. The toxicity values and estimated RfDs are summarized in the product-specific attachments.

### 2.3.2 Components

As stated in Section 1.2.1, this risk assessment characterized the toxicity of the product formulations as a whole, as well as the toxicity of some of their ingredients, based on defined criteria (see below). Some of the identified ingredients may not be present in their original form in the end product. That is, some ingredients may be “reactants,” which are chemicals added to the ingredient mixture that are intended to react with other ingredients, resulting in the composition and characteristics of the end product. For example, a small amount of a strong acid or base can adjust the pH of the mixture of ingredients that comprise a product, and it would be consumed during the chemical reaction of pH adjustment. However, that strong acid or base is still listed as an ingredient and therefore is evaluated in this risk assessment, even though it may only be present in trace (if any) amounts in the end product used in wildland firefighting. Similarly, the primary “water enhancing” chemical in a product may be created by the reaction of two or more chemical ingredients that are consumed in the reaction and not present in their original form. These also would be listed as ingredients and considered as such in this risk assessment. This comprehensive approach to assessing risk could overestimate risk from a specific ingredient that serves as a reactant. In the examples provided, the risk assessment results could include risks that would be associated with chemical burns or tissue corrosion from exposure to a strong acid or base, or potential carcinogenicity from a reactant not present in the final product. At a screening level, this approach is considered efficient and appropriate. If a risk threshold is exceeded for a reactant that is partially or completely consumed, the Forest Service would coordinate with the manufacturer and pursue further evaluation, such as requesting data identifying the unreacted amount, if any, of the chemical of concern in the final product and analyzing the related risk.

In addition to evaluating the risks to workers and members of the public from the wildland firefighting product formulations, several individual ingredients in the formulations were targeted for quantification of the risk that they may present. These ingredients meet one or more of the following criteria:

- It is a suspected or known carcinogen by a relevant route of exposure, and a cancer slope factor is available for that exposure route.
- The oral LD<sub>50</sub> in laboratory animals is less than 500 mg/kg.
- The chemical is listed on the formulation's safety data sheet as a toxic chemical reportable under SARA Section 313.

### 2.4 Data Gaps

The hazard assessment of the products and their ingredients may include one or more of the following data gaps, which are listed in the product-specific attachments:

- No long-term toxicity tests were available for the products as a whole. RfDs were estimated based on acute toxicity data and the methodology described by Layton et al. (1987).
- Dermal penetration rates were unavailable for most of the chemical ingredients. In the absence of dermal absorption data, a rate of 1 percent per 8 hours was used for inorganic chemicals, and a rate of 10 percent per 8 hours was used for organic chemicals. For the formulated product (a chemical mixture), a rate of 1 percent per 8 hours was used.
- If toxicity data are not available for a specific ingredient, risks from that ingredient were not evaluated. Any such cases are noted in the product-specific data in Appendix A.
- If a cancer slope factor is unavailable for a chemical that is identified as a potential carcinogen, a cancer risk estimate for the chemical could not be quantified. Any such cases are noted in the product-specific data in Appendix A.

## 3.0 EXPOSURE ASSESSMENT

### 3.1 Introduction

This section describes the human populations potentially exposed to water enhancers and the scenarios for which doses were estimated. There are two populations potentially at risk: (1) wildland fire-fighters and (2) members of the public. Fire-fighters include airtanker base personnel, helitack crews, smokejumpers, hotshot crews, type 2 firefighters, engine crews, and overhead workers. The public includes individuals who may be near the scene of an application of a water enhancer, or who live or work at a house or other structure to which a water enhancer was applied.

### 3.2 Exposure and Dose

Two primary conditions are necessary for a human to receive a chemical dose that may result in a toxic effect. First, the chemical must be present in the person's immediate environment—in the air, on a surface such as vegetation that may contact the skin, or in food or water—so that it is available for intake. The amount of the chemical present in the person's immediate environment is the exposure level. Second, the chemical must enter the person's body by some route. Chemicals on vegetation, on clothing that is in contact with the skin, or on the skin itself, may penetrate the skin. Chemicals in food or water may be ingested. The amount of a chemical that moves into the body by any of those routes constitutes the dose. While two people may be subjected to the same level of exposure (for example, two workers walking through vegetation treated with a water enhancer), one may get a much lower dose than the other by wearing protective clothing or washing as soon as possible. Exposure, then, is the amount of a chemical available for intake into the body; dose is the amount of the substance that actually enters the body.

### 3.3 Potential Exposures

This subsection describes the populations that may be exposed to water enhancers and lists the representative human health exposure scenarios analyzed in this risk assessment.

#### 3.3.1 Affected Populations and Exposure Scenarios

The human population that could be exposed to water enhancers falls into two groups. The first group is the workers directly involved in their use, including airtanker base personnel, firefighters, and workers who enter areas where the chemicals have been applied. The second group is the public who may be subject to non-occupational exposure.

Airtanker base personnel, helitack crews, smokejumpers, hotshot crews, type 2 firefighters, engine crews, and overhead workers include both male and female workers. Therefore, risks to each were assessed separately, using gender-specific body weight and skin surface area data. This risk assessment used mean body weights of 84.0 and 70.2 kg for male and female fire-fighters, respectively, between 30 and 40 years old (EPA 2011).



Members of the public may be exposed as a result of cleaning a structure, and may include both adults and children. For members of the public, it was assumed that an adult (male or female) weighs an average of 80 kg (176 lb), and a 6- to 11-year-old child weighs 31.8 kg (70 lb) (EPA 2011).

The accidental drench of an individual in the path of an aerial drop of water enhancer was also evaluated. Although a fire-fighter would be more likely to be exposed in an accidental drench scenario, this exposure was also estimated for members of the public.

### 3.3.2 Levels of Exposure

To allow for some of the uncertainty inherent in any quantitative risk assessment, two levels of human exposure were evaluated.

**Typical Exposures.** Typical exposure assumptions attempt to target the average dose an individual may receive if all exposure conditions are met. These assumptions include the average duration of exposure, typical number of days worked per year, and other similar assumptions.

**Maximum Exposures.** Maximum exposure assumptions attempt to define the upper bound of credible doses that an individual may receive if all exposure conditions are met. These assumptions include an estimate of the maximum duration of exposure, the maximum number of days worked per year, and other similar assumptions.

## 3.4 Potential Exposures to Workers

The doses to workers were estimated for each type of worker, using the assumptions described below about their activities and exposures.

### 3.4.1 Airtanker Base Personnel

Airtanker base personnel include both mixmasters and loaders. Frequently, a single individual carries out both functions. They unload water enhancer concentrate when received from suppliers, prepare mixed water enhancer by blending dry or liquid concentrate with water and wash down spills from ramps and storage areas. Protective clothing includes a dust mask, eye and ear protection, cotton overalls, and leather or fabric shoes. A hard hat may also be used, especially near the airtankers.

Exposures to mixers were assumed to result from both dermal and inhalation exposure to powdered water enhancer product concentrates. For dermal exposure, the mean daily solids adherence factors for skin recommended in EPA (2011) were used: 0.0982, 0.1859, 0.2763, and 0.0660 mg/cm<sup>2</sup> of surface area for the face, arms, hands, and legs, respectively, all based on measured solids adherence for construction workers. For inhalation exposure, the retardant concentration of 4.43 mg/m<sup>3</sup> that was measured in a monitoring study at airtanker bases (USFS 1979) was assumed to be similar to a water enhancer concentration that would be present in the air at the mixing station. The mixers were assumed to be exposed to this concentration for either a typical mixing shift of two hours or a maximum shift of 10 hours, at an inhalation rate of 1.62

m<sup>3</sup>/hour (moderate intensity physical activity for adult in their 30s) (EPA 2011) at 10 percent absorption efficiency of the chemicals by the lungs. The concentration of water enhancer in inhaled air is estimated to be reduced by 90 percent when the mixers use a dust mask.

The loaders were assumed to be exposed to mixed water enhancer as a result of spills over the hands and forearms. This was assumed to create a layer on the skin that that would be absorbed, with the amount on the skin varying based on whether the liquid was partially wiped off (typical) or not wiped off (maximum), using the exposure factors in EPA (2011). There are four (typical) or 55 (maximum) loading events per day.

Both mixers and loaders are assumed to have a 12-year career, working 37 days per year in the typical case and 120 days per year in the maximum case. It is assumed that two (typical) or 10 (maximum) hours elapse until the chemical is completely washed off by showering and changing clothes.

### **3.4.2 Helitack Crews**

Helitack crews arrive at a fire by helicopter and stay on site for the duration of the fire. Protective clothing includes a helmet (hard hat when on the ground), eye and ear protection, Nomex<sup>®</sup> fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Helitack crew members were assumed to be exposed to water enhancer residues by walking through an area where vegetation has been treated. This scenario assumes that 75 percent of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. These individuals are assumed to have a seven-year career, with 25 days per year (typical) or 100 days per year (maximum) when they encounter treated vegetation. Two (typical) or four (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

### **3.4.3 Smokejumpers**

Smokejumpers parachute into the area of a fire and stay on site for the duration of the fire or until they are replaced with other firefighters. Protective clothing includes a helmet (hard hat when on the ground), eye and ear protection, Nomex<sup>®</sup> fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Smokejumpers were assumed to be exposed to water enhancer residues by walking through an area where vegetation has been treated. The risk assessment assumes that 75 percent of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. Smokejumpers were assumed to have a 10-year career, with seven days per year (typical) or 20 days per year (maximum) when they encounter treated vegetation, and 2 (typical) or 7 (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

### 3.4.4 Hotshot Crews

Hotshot crews are specialized fire-fighters, the first reinforcements after initial attack. They are used in suppression of large fires, and build and reinforce fire lines. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Hotshot crew members were assumed to receive exposure to water enhancer residues by walking through an area where vegetation has been treated. The scenario assumes that 75 percent of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. These individuals are associated with a 7-year career, with 20 days per year (typical) or 40 days per year (maximum) when they encounter treated vegetation, and 3 (typical) or 7 (maximum) hours elapsing until the chemical is washed off thoroughly by showering and changing clothes.

### 3.4.5 Type 2 Firefighters

Type 2 firefighters act as reinforcements on large fires. They do mop-up and patrol the control lines. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Type 2 firefighters were assumed to be exposed to water enhancer residues by walking through an area where vegetation has been treated, and by mixing and applying water enhancers to structures. The vegetation contact exposure assumes that 75 percent of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. For water enhancer mixing and application activities, it was assumed that mixture spills over hands and forearms each time a load is mixed and applied. This was assumed to create a layer on the skin that that would be absorbed, with the amount on the skin varying based on whether the liquid was partially wiped off (typical) or not wiped off (maximum), using the exposure factors in EPA (2011). There are four (typical) or 55 (maximum) loading events per day. They are assumed to have an eight-year career, with two days per year (typical) or six days per year (maximum) when they encounter treated vegetation or mix/apply water enhancers. It was assumed that two (typical) or six (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

### 3.4.6 Engine Crews

Engine crews may mix water enhancer concentrates with water, and apply them in support of fire-fighting activities. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Worker exposure parameters for ground-based water enhancer application by engine crews could range widely. This exposure scenario is evaluated qualitatively in this risk assessment. In general, members of engine crews could be exposed to ground-applied water enhancers when walking through an area where vegetation has been treated, and by mixing and applying water enhancer products. In either case, their exposure would be expected to be no more than that of

hotshot crews from walking through treated vegetation, nor any greater than mixers or loaders at airtanker bases.

### **3.4.7 Overhead Workers**

Overhead workers oversee an assigned portion of the fire operations. They inspect and supervise from the fire line. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Overhead workers were assumed to be exposed to water enhancer residues when walking through an area where vegetation has been treated. The risk assessment assumes that 75 percent of the front half of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. Overhead workers are assumed to have a 15-year career, with 2 days per year (typical) and 6 days per year (maximum) when they encounter treated vegetation. It is further assumed that two (typical) or six (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

### **3.4.8 Rehabilitation Teams**

Members of rehabilitation teams could encounter dried chemical residues as they assess fire damage and plan/implement measures to minimize secondary damage to the environment (such as mud slides). Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, and leather fire gloves. These workers have an average 10-year career in this job function, with 2 (typical) or 6 (maximum) days per year of exposure at 2 (typical) or 6 (maximum) hours of exposure per day. Risks to rehabilitation team members were addressed qualitatively.

### **3.4.9 Lifetime Doses to Workers**

The lifetime doses for workers handling potential carcinogens were estimated assuming that 95 percent of the time the worker is exposed to the typical dose for the typical number of days per year, and 5 percent of the time the worker is exposed to the maximum dose for the maximum number of days per year. Annual doses were multiplied by the estimated career length to indicate cumulative exposure, which was then averaged over the typical 75-year (males) or 80-year (females) lifetime, based on EPA (2011).

## **3.5 Potential Exposures to Members of the Public**

The doses to members of the public from exposure to water enhancers were estimated for one exposure scenario: cleaning a structure. In this analysis, doses from the dermal route of exposure were estimated. The following section describes the parameters used in calculating these doses. Several additional types of potential exposure to members of the public were evaluated qualitatively.

### **3.5.1 Quantitative Analysis: Cleaning a Structure**

This scenario assumes that, while an adult male or female is cleaning a structure to which a water enhancer was applied, aqueous rinsate (in a dilution the same as the mixture strength) is dispersed over hands and forearms during pressure washing or observation of cleaning activities. This was assumed to create a layer on the skin that would be absorbed, with the amount on the skin varying based on whether the liquid was partially wiped off (typical) or not wiped off (maximum), using the exposure factors in EPA (2011). The same level of exposure was assumed to occur for a child observing this activity as his or her own home is cleaned. The exposure duration is one hour.

### **3.5.2 Qualitative Analyses**

Potential public exposures that were addressed qualitatively in the risk discussion include the following:

- Individuals re-entering areas to which water enhancer had been applied; this may include individuals such as hikers, researchers, hunters, biologists, or children playing in the area.
- Individuals harvesting mushrooms, morels, or berries from wildlands after vegetative regrowth has occurred.
- Individuals consuming vegetables from home gardens.
- Individuals handling pets that re-entered areas to which water enhancer had been applied.
- Salvage logging of burned areas, in which an individual has contact for up to four hours per day twice per year for two years.

### **3.5.3 Lifetime Doses to Members of the Public**

Lifetime doses to members of the public were calculated for the potential carcinogens evaluated in this risk assessment. The lifetime dose was estimated by assuming that an individual participates in cleaning a structure once in his or her lifetime. The estimated dose from this activity was averaged over a 78-year lifetime (EPA 2011).

## **3.6 Potential Exposure from Accidental Drench**

In the event of an accidental drench, workers or members of the public may be exposed to greater amounts of a water enhancer than under the previously described routine exposure circumstances.

### **3.6.1 Workers**

The accident scenario in which a worker is drenched by an aerial drop of water enhancer was assessed by assuming that the application rate of the chemical is received on 50 percent of the

body surface area, with a 90% reduction in exposure due to protective clothing and 2 hours elapses until the individual is able to shower and change clothes. The potential frequency of this accident is assumed to be once per year over a 12-year career.

### **3.6.2 Members of the Public**

The accident scenario in which an adult or child is drenched by an aerial drop of water enhancer was also assessed. In this scenario, the application rate of the chemical is received on 50 percent of the body surface area. This event is assumed to occur no more than once in an individual's lifetime.

## 4.0 RISK CHARACTERIZATION

### 4.1 Introduction

This section characterizes the estimated risks to the health of workers and members of the public that may result from any of the water enhancers on the Forest Service's QPL. In the risk characterization, the human doses estimated in the exposure assessment (Section 3.0) are compared with the toxicity characteristics described in the hazard assessment (Section 2.0), to arrive at estimates of risk.

Section 4.2 describes the methods used to evaluate human health risks, including both noncarcinogenic and carcinogenic risks. Section 4.3 summarizes the results of the quantitative risk characterization for the currently evaluated water enhancer products, and individual ingredients within them. Section 4.4 discusses several additional exposure scenarios that were addressed qualitatively, and Section 4.5 discusses the uncertainties in this risk assessment.

### 4.2 Methodology for Assessing Risks

All of the products on the QPL are mixtures of several ingredients. Risks from these mixtures were evaluated following the recommendations of EPA (2000): *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*. Specifically, the following approaches were applied:

- EPA states that "whenever possible, the preferred approach to the health risk evaluation of chemical mixtures is to perform the assessment using health effects and exposure data on the whole mixture." To accomplish this, risks were calculated for the formulated products as a whole, using the RfDs that were estimated for each product as described in Section 2.3.1 and presented in Appendix A.
- EPA also stated that "even if a risk assessment can be made using whole-mixture data, it may be desirable to also conduct a risk assessment based on toxicity data on the components in the mixture . . . When a mixture contains component chemicals whose critical effects are of major concern, e.g., cancer or developmental toxicity, an approach based on the mixture data alone may not be sufficiently protective in all cases." This additional analysis was deemed particularly important in the case of the water enhancers because only acute toxicity data were available on the products as a mixture. Therefore, each formulation was reviewed for components that meet the criteria presented in Section 2.3.2.

The assessment of risks for the products and for the targeted ingredients was conducted following the standard risk assessment methodology described in NRC (1983) and EPA (1989).

#### 4.2.1 Noncarcinogenic Risk Estimation

In this risk assessment, the potential risks were evaluated by comparing the representative doses (estimated in the exposure assessment) with the RfDs (identified in the hazard assessment). All the RfDs used in this risk analysis take into account the possibility of multiple exposures and

represent acceptable dose levels. The comparison of dose to RfD consists of a simple ratio, called the Hazard Quotient:

$$\text{Hazard Quotient} = \frac{\text{Estimated Dose (mg / kg / day)}}{\text{RfD (mg / kg / day)}}$$

If the estimated dose does not exceed the RfD, the hazard quotient will be one or less, indicating a negligible risk of noncarcinogenic human health effects. It is important to note two characteristics of the hazard quotient: (1) the greater the value of the hazard above one, the greater the level of concern; but (2) the level of concern does not increase linearly as the hazard quotient increases, because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects. Thus, the interpretation of the potential toxic response associated with a particular hazard quotient can range widely depending on the chemical (EPA 1989).

A dose estimate that exceeds the RfD, although not necessarily leading to the conclusion that there will be toxic effects, clearly indicates a potential risk for adverse health effects. Risk is presumed to exist if the hazard quotient is greater than one. However, comparing one-time or once-a-year doses (such as those experienced by the public or in an accident) to RfDs that are designed to represent long-term exposures with repeated daily doses tends to exaggerate the risk from those infrequent events.

For workers and the public, hazard quotients were computed for each product and targeted ingredient for typical, maximum, and accident situations. If the hazard quotient exceeds one, the risk may require mitigation, depending on the circumstances of exposure.

Following the guidance presented in EPA (2000), the additive approach was used to sum the hazard quotients when more than one targeted ingredient was identified in a product. In these cases, a hazard index for the product, representing the sum of the hazard quotients, was calculated. The hazard index is interpreted in the same manner as the hazard quotient; that is, risk is presumed to exist if the product hazard index exceeds one.

#### **4.2.2 Cancer Risk Estimation**

The mechanism for cancer dose-response can be complex. In 2005, EPA updated agency guidance (EPA 2005) for deriving cancer slope factors, as described in Section 2.1.4 of this report. Historically, carcinogenic effects were assumed to have no threshold, requiring extrapolation to compare exposures from the much lower doses associated with environmental exposure to chemicals. However, new perspectives on methods to assess risks of cancer are gaining wider acceptance, such as consideration of mode of action, thresholds for carcinogenicity, and incorporating other types of biological data. Estimation of cancer slope factors using updated methods is occurring on a chemical-by-chemical basis, as new laboratory studies are completed and new risk assessments are conducted. For any chemical identified as a known or potential human carcinogen in this risk assessment, the chemical-specific approach developed by EPA for estimating its cancer risk is applied.



When the cancer slope factor approach is recommended by EPA for estimating human cancer risk from a chemical, the cancer risk is expressed as the probability that cancer will occur over the course of a person's lifetime, as a result of the stated exposure. This risk probability is calculated as follows:

$$RISK = DOSE \times CSF \times OCC / LIFE$$

where:

RISK	=	the lifetime probability of cancer as a result of the specified exposure
DOSE	=	estimated dose (mg/kg/day)
CSF	=	cancer slope factor (per mg/kg/day)
OCC	=	number of occurrences of the daily dose during an individual's lifetime
LIFE	=	the number of days in a lifetime (in 75 years for male workers, 80 years for female workers, and 78 years for members of the public of either gender)

The resulting cancer probability is compared to a benchmark value of  $1 \times 10^{-6}$  (or 1 in 1 million), a value commonly accepted in the scientific community as representing a cancer risk that would result in a negligible addition to the background cancer risk of approximately 38 percent in the United States (NCI 2018). In some occupational health risk assessments, cancer risks as high as  $1 \times 10^{-4}$  (1 in 10,000) can be considered acceptable. However, the benchmark of 1 in 1 million is used for both workers and the public in this risk assessment.

### 4.3 Current Risk Summary (October 2020)

This section summarizes the health risk assessments for the water enhancers listed on the October 5, 2020, QPL at <https://www.fs.fed.us/rm/fire/wfcs/index.htm>, including conditionally or interim qualified products. Any time the QPL is updated, the current applicability of this section of this report will change. This section will be updated as federal agency resources and priorities allow.

#### Estimated Risks from the Formulations

Appendices A and B present product-specific information and estimates of the formulated products' health risks to workers and the public from routine uses and accident scenarios.

For typical exposures, based on the toxicity of the product as a whole, all products resulted in hazard quotients less than one, indicating negligible risk to fire-fighting personnel from the water enhancer products under typical conditions of exposure. In the maximum scenarios, the hazard quotients for two products (the uncolored and colored variant of the same product) exceeded one, indicating a risk for male and female airtanker base personnel mixing FireIce 561 and Fire Ice 561 Cool Blue-F. Forest Service policy does not allow application of water enhancers from large multi-engine airtankers, but this scenario is assessed for the information of those agencies whose policy permits this use.

Based on the toxicity of the product as a whole, no risks were predicted for adult and child members of the public cleaning a structure that had been treated with a water enhancer.

Estimated risks to workers and members of the public from an accidental drench with a water enhancer are also presented in Appendices A and B. Hazard quotients based on the toxicity of each product as a whole indicated negligible risk from all products.

## **4.4 Qualitative Risk Evaluations**

### **4.4.1 Rehabilitation Team Members**

Rehabilitation teams may encounter dried water enhancer residue. The estimated daily exposure is comparable to that of overhead workers, although the residues would be dried by the time the rehabilitation team enters the area, resulting in a much lower rate of dermal transfer and absorption. Risks are expected to generally be negligible, not exceeding those predicted for overhead workers in the typical or maximum scenarios. Please refer to Section 4.3 for a current summary of those risks, and to Appendix A for product-specific estimates.

### **4.4.2 Re-Entry to Treated Areas**

Individuals such as hikers, researchers, hunters, biologists, or children playing could re-enter areas to which water enhancer has been applied. These exposures are expected to generally result in a negligible risk, similar to and no greater than those of rehabilitation team members. Please refer to Section 4.3 for a current summary of those risks, and to Appendix A for product-specific estimates.

### **4.4.3 Harvesting Wild Vegetation**

Individuals may harvest mushrooms, morels, berries from wildlands after vegetative regrowth has occurred, in areas that were treated with water enhancers. The dermal exposure from harvesting these edibles is expected to generally present negligible risk, and would be similar to the exposure of rehabilitation team members, hunters, ecologists, or others who re-enter treated areas. Please refer to Section 4.3 for a current summary of those risks, and to Appendix A for product-specific estimates.

### **4.4.4 Ingesting Vegetables or Wild Vegetation**

Individuals are advised against consuming vegetables from home gardens to which water enhancer may have been applied, or from areas in wildlands where residues are apparent.

### **4.4.5 Handling Pets with Exposure to Treated Vegetation**

Handling dogs or other domestic animals whose fur contains residues as a result of exposure to vegetation in treated areas is not expected to pose risks to humans any greater than those that would be associated with direct vegetation contact, as described in Section 4.4.2.

### **4.4.6 Salvage Logging**

Salvage logging may take place in burned areas, in which an individual has contact for up to four hours per day twice per year for two years. This daily exposure of four hours exceeds the typical duration of vegetation contact predicted for most fire-fighters in the typical scenarios, but is bounded by higher exposures (up to seven hours) for vegetation contact in some maximum scenarios. In general, negligible risks are predicted for salvage loggers from water enhancers.

Please refer to Section 4.3 for a current summary of the comparable risks to fire-fighters, particularly those in the maximum exposure scenarios, and to Appendix A for product-specific estimates.

## 4.5 Discussion and Uncertainties

The risks summarized in this assessment are not probabilistic estimates of risk, but are conditional estimates. That is, these risks are likely only if all exposure scenario assumptions that were described are met. The primary areas of uncertainty in this analysis include the predicted RfDs and dermal penetration rates for each formulation and ingredient, and the quantity of a chemical to which an individual may actually be exposed. For individual ingredients with RfDs based on subchronic or chronic studies, more confidence can be placed in the degree to which they represent actual acceptable intake levels. In most cases, no dermal penetration data are available, so reasonable estimates (see details throughout Section 3.4) were applied in the assessment. Although monitoring studies could identify some levels of exposure more accurately, the highly variable nature of fire-fighting activities would require application of a large margin of error, limiting their utility in providing greater confidence in the risk conclusions.

Exposure durations for workers were estimated by Forest Service personnel with years of experience in the fire-fighting program. If longer durations of exposure occur in the field, with no increase in frequency of washing or showering, then a comparable increase in the estimated dose and risk would be predicted. For any hazard quotients that were estimated to be between 0.1 and 1, such a change in exposure duration could increase the hazard quotient to the point where it would exceed the threshold value of one, at which point a potential health risk would be indicated in this type of predictive assessment. In general, this situation may primarily apply to exposures to mixers of powdered water enhancer at airtanker bases; this risk can be mitigated by removing any powder residue from exposed skin by washing with water. Based on products evaluated to date, increases in exposure duration for helitack crews, smokejumpers, hotshot crews, type 2 firefighters, engine crews, and overhead workers would still likely result in estimated risks that remain far below the level of concern.

It is important to note that, during the many years of these chemicals' use in fire-fighting, reports of adverse health effects have been limited to skin and eye irritation, and potential allergic reactions. This use history does not appear to warrant extensive testing, given the use of these products during emergency response.

## 5.0 REFERENCES

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## Appendix A

# Health Risk Assessments for Water Enhancers on Qualified Products List

### October 2020

Barricade II  
BioCentral Blazetamer 380  
Firelce 561 (formerly GelTech Firelce)  
Firelce 561 Cool Blue-F (formerly GelTech Firelce Cool Blue-F)  
Firewall II (formerly Wildfire AFG Firewall II)  
Phos-Chek Insul-8  
Thermo-Gel 200L  
Thermo-Gel 200L Blue Mixed Product (formerly Thermo-Gel 200L AV-B1 (Blue))  
Thermo-Gel 500P

**Scientific notation:** Some of the risk tables in this section use scientific notation, since many of the values are very small. For example, the notation 3.63E-001 represents  $3.63 \times 10^{-1}$ , or 0.363. Similarly, 4.65E-009 represents  $4.65 \times 10^{-9}$ , or 0.00000000465.

**Boldface** type is used in these tables to indicate the risks for which the hazard quotient, hazard index, or cancer risk exceeds the acceptable value, indicating risk in that scenario; that is, the risk value is in boldface type if the hazard index or hazard quotient is greater than 1, or the cancer risk is greater than 1 in 1 million.

## Barricade II

### Product Data

Concentrate form:	Liquid
Mix ratio:	0.03 gal conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

Estimated Risks from Formulation				
	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Airtanker base personnel - loading	5.95E-04	5.61E-04	3.61E-02	3.33E-02
Helitack crews	1.11E-05	1.17E-05	2.23E-05	2.34E-05
Smokejumpers	1.11E-05	1.17E-05	3.90E-05	4.09E-05
Hotshot crews	1.67E-05	1.75E-05	3.90E-05	4.09E-05
Type 2 firefighters	1.11E-05	1.17E-05	3.34E-05	3.51E-05
Overhead workers	1.11E-05	1.17E-05	3.34E-05	3.51E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	4.77E-05	5.74E-05	6.09E-05	7.34E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	1.03E-02	1.08E-02	5.06E-02	6.97E-02

## BioCentral Blazetamer 380

### Product Data

Concentrate form:	Liquid
Mix ratio:	0.0065 gal conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

Estimated Risks from Formulation				
	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Airtanker base personnel - loading	1.14E-04	1.07E-04	6.91E-03	6.62E-03
Helitack crews	2.13E-06	2.24E-06	4.26E-06	4.47E-06
Smokejumpers	2.13E-06	2.24E-06	7.46E-06	7.83E-06
Hotshot crews	3.20E-06	3.35E-06	7.46E-06	7.83E-06
Type 2 firefighters	2.13E-06	2.24E-06	6.39E-06	6.71E-06
Overhead workers	2.13E-06	2.24E-06	6.39E-06	6.71E-06
Public: cleaning a structure	Adult	Child	Adult	Child
	9.12E-06	1.10E-05	1.17E-05	1.41E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	1.96E-03	2.07E-03	9.69E-03	1.33E-02



## FireIce 561

### Product Data

Concentrate form:	Powder
Mix ratio:	0.18 lb/gal
Formulation Oral LD <sub>50</sub> :	>505 mg/kg
Formulation RfD:	0.0253 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

Estimated Risks from Formulation				
	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	1.32E-01	1.44E-01	<b>2.85E+00</b>	<b>2.78E+00</b>
Airtanker base personnel - loading	3.79E-03	3.57E-03	2.30E-01	2.13E-01
Helitack crews	7.09E-05	7.44E-05	1.42E-04	1.49E-04
Smokejumpers	7.09E-05	7.44E-05	2.48E-04	2.60E-04
Hotshot crews	1.06E-04	1.12E-04	2.48E-04	2.60E-04
Type 2 firefighters	7.09E-05	7.44E-05	2.13E-04	2.23E-04
Overhead workers	7.09E-05	7.44E-05	2.13E-04	2.23E-04
Public: cleaning a structure	Adult	Child	Adult	Child
	3.03E-04	3.65E-04	3.88E-04	4.67E-04
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	6.53E-02	6.88E-02	3.22E-01	4.43E-01

## FireIce 561 Cool Blue-F

### Product Data

Concentrate form:	Powder
Mix ratio:	0.1844 lb/gal
Formulation Oral LD <sub>50</sub> :	>505 mg/kg
Formulation RfD:	0.0253 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

Estimated Risks from Formulation				
	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	1.32E-01	1.44E-01	<b>2.85E+00</b>	<b>2.78E+00</b>
Airtanker base personnel - loading	3.88E-03	3.66E-03	2.35E-01	2.18E-01
Helitack crews	7.26E-05	7.62E-05	1.45E-04	1.52E-04
Smokejumpers	7.26E-05	7.62E-05	2.54E-04	2.67E-04
Hotshot crews	1.09E-04	1.14E-04	2.54E-04	2.67E-04
Type 2 firefighters	7.26E-05	7.62E-05	2.18E-04	2.29E-04
Overhead workers	7.26E-05	7.62E-05	2.18E-04	2.29E-04
Public: cleaning a structure	Adult	Child	Adult	Child
	3.11E-04	3.74E-04	3.97E-04	4.79E-04
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	6.69E-02	7.05E-02	3.30E-01	4.54E-01

## FireIce HVB-Fx

### Product Data

Concentrate form:	Powder
Mix ratio:	0.23 lb conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,000 mg/kg
Formulation RfD:	0.25 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

### Estimated Risks from Formulation

	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	1.34E-02	1.46E-02	2.88E-01	2.81E-01
Airtanker base personnel - loading	4.12E-04	3.88E-04	2.50E-02	2.36E-02
Helitack crews	9.15E-06	9.60E-06	1.83E-05	1.92E-05
Smokejumpers	9.15E-06	9.60E-06	3.20E-05	3.36E-05
Hotshot crews	1.37E-05	1.44E-05	3.20E-05	3.36E-05
Type 2 firefighters	4.21E-04	3.96E-04	9.80E-03	9.24E-03
Overhead workers	9.15E-06	9.60E-06	2.74E-05	2.88E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	3.30E-07	3.98E-07	4.22E-07	5.08E-07
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	8.42E-03	8.88E-03	4.42E-02	5.72E-02

## Firewall II

### Product Data

Concentrate form:	Liquid
Mix ratio:	0.03 gal conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

### Estimated Risks from Formulation

	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Airtanker base personnel - loading	5.53E-04	5.22E-04	3.36E-02	3.09E-02
Helitack crews	1.03E-05	1.09E-05	2.07E-05	2.17E-05
Smokejumpers	1.03E-05	1.09E-05	3.62E-05	3.80E-05
Hotshot crews	1.55E-05	1.63E-05	3.62E-05	3.80E-05
Type 2 firefighters	1.03E-05	1.09E-05	3.10E-05	3.26E-05
Overhead workers	1.03E-05	1.09E-05	3.10E-05	3.26E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	4.43E-05	5.34E-05	5.66E-05	6.82E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	9.53E-03	1.00E-02	4.71E-02	6.47E-02

## Phos-Chek Insul-8

### Product Data

Concentrate form:	Liquid
Mix ratio:	0.03 gal conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

### Estimated Risks from Formulation

	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Airtanker base personnel - loading	5.06E-04	4.77E-04	3.07E-02	2.83E-02
Helitack crews	9.46E-06	9.93E-06	1.89E-05	1.99E-05
Smokejumpers	9.46E-06	9.93E-06	3.31E-05	3.47E-05
Hotshot crews	1.42E-05	1.49E-05	3.31E-05	3.47E-05
Type 2 firefighters	9.46E-06	9.93E-06	2.84E-05	2.98E-05
Overhead workers	9.46E-06	9.93E-06	2.84E-05	2.98E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	4.05E-05	4.88E-05	5.18E-05	6.24E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	8.71E-03	9.18E-03	4.30E-02	5.92E-02

## Thermo-Gel 200L

### Product Data

Concentrate form:	Liquid
Mix ratio:	0.03 gal conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

Estimated Risks from Formulation				
	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Airtanker base personnel - loading	5.53E-04	5.22E-04	3.36E-02	3.09E-02
Helitack crews	1.03E-05	1.09E-05	2.07E-05	2.17E-05
Smokejumpers	1.03E-05	1.09E-05	3.62E-05	3.80E-05
Hotshot crews	1.55E-05	1.63E-05	3.62E-05	3.80E-05
Type 2 firefighters	1.03E-05	1.09E-05	3.10E-05	3.26E-05
Overhead workers	1.03E-05	1.09E-05	3.10E-05	3.26E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	4.43E-05	5.34E-05	5.66E-05	6.82E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	9.53E-03	1.00E-02	4.71E-02	6.47E-02

## Thermo-Gel 200L Blue Mixed Product

### Product Data

Concentrate form:	Liquid
Mix ratio:	0.03 gal conc/gal mix
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

Estimated Risks from Formulation				
	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Airtanker base personnel - loading	5.55E-04	5.23E-04	3.37E-02	3.10E-02
Helitack crews	1.04E-05	1.09E-05	2.08E-05	2.18E-05
Smokejumpers	1.04E-05	1.09E-05	3.64E-05	3.81E-05
Hotshot crews	1.56E-05	1.63E-05	3.64E-05	3.81E-05
Type 2 firefighters	1.04E-05	1.09E-05	3.12E-05	3.27E-05
Overhead workers	1.04E-05	1.09E-05	3.12E-05	3.27E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	4.44E-05	5.36E-05	5.68E-05	6.85E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	9.56E-03	1.01E-02	4.72E-02	6.50E-02

## Thermo-Gel 500P

### Product Data

Concentrate form:	Powder
Mix ratio:	0.1 lb/gal
Formulation Oral LD <sub>50</sub> :	5,050 mg/kg
Formulation RfD:	0.2525 mg/kg/day
Mixture application rate:	0.06 gal/ft <sup>2</sup>

### Estimated Risks from Formulation

	Hazard Quotient			
	Typical Scenario		Maximum Scenario	
	Male	Female	Male	Female
Airtanker base personnel - mixing	1.32E-02	1.44E-02	2.85E-01	2.78E-01
Airtanker base personnel - loading	2.10E-04	1.98E-04	1.28E-02	1.20E-02
Helitack crews	3.94E-06	4.13E-06	7.87E-06	8.26E-06
Smokejumpers	3.94E-06	4.13E-06	1.38E-05	1.45E-05
Hotshot crews	5.91E-06	6.20E-06	1.38E-05	1.45E-05
Type 2 firefighters	3.94E-06	4.13E-06	1.18E-05	1.24E-05
Overhead workers	3.94E-06	4.13E-06	1.18E-05	1.24E-05
Public: cleaning a structure	Adult	Child	Adult	Child
	1.68E-05	2.03E-05	2.15E-05	2.60E-05
Drench (accident)	Worker (male)	Worker (female)	Public (adult)	Public (child)
	3.63E-03	3.82E-03	1.79E-02	2.46E-02



# Appendix B: Health Risk Assessments for Conditionally or Interim Qualified Water Enhancer Products October 2020

None at this time.

**Scientific notation:** Some of the risk tables in this section use scientific notation, since many of the values are very small. For example, the notation 3.63E-001 represents  $3.63 \times 10^{-1}$ , or 0.363. Similarly, 4.65E-009 represents  $4.65 \times 10^{-9}$ , or 0.00000000465.

**Boldface** type is used in these tables to indicate the risks for which the hazard quotient, hazard index, or cancer risk exceeds the acceptable value, indicating risk in that scenario; that is, the risk value is in boldface type if the hazard index or hazard quotient is greater than 1, or the cancer risk is greater than 1 in 1 million.