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# Draft Human Health and Ecological Risk Assessment for Dichlorvos (DDVP) in Exotic Fruit Fly Applications

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## EXECUTIVE SUMMARY

The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ) is proposing the use of dichlorvos (DDVP) strips in traps in its cooperative exotic fruit fly eradication program. DDVP is an organophosphate insecticide contained in insecticidal strips within a trap designed to attract and kill exotic fruit flies.

USDA-APHIS evaluated the potential human health and ecological risks from the proposed use of the Hercon<sup>®</sup> Vaportape<sup>™</sup> II DDVP and the Plato Industries Insecticide Strip formulations and determined that the risk to human health and the environment is negligible. The lack of risk to human health and the environment is based on the low probability of exposure to people and the environment, and favorable environmental fate and effects data. DDVP has high acute dermal toxicity, and moderate acute oral and inhalation toxicity to mammals. DDVP is a mild eye and skin irritant. The proposed use of DDVP-impregnated strips in traps, and adherence to label requirements, substantially reduces the potential for exposure to humans and the environment, including non-target fish and wildlife. Adverse health risks to workers are not expected based on the application method and low potential for exposure to DDVP when applied according to label directions including PPE. Adverse health effects for a worker from accidental inhalation are not expected because both the assembly and placement of traps are outdoors. Adverse health risk for workers from accidental dermal exposure to a DDVP strip during trap assembly is not expected because risk estimates are below levels of concern. Adverse health effects for the general public are not expected based on requirements for public notification as specified on the label, the placement of traps out of the normal reach of children, and destruction of fruit in treated areas as part of the program. Risk estimates for a child (pre-teenager ages 10 to 12 years) from accidental dermal exposure to a DDVP strip are below levels of concern.

Off-site movement of DDVP is minimized by the application method (traps) and environmental fate (rapid degradation) of the product. The use of DDVP pest strips in traps reduces exposure and risk to non-target vertebrates and invertebrates. Sensitive terrestrial invertebrates that contact the strip inside the trap would be at risk, but these effects would be incidental and localized to individual traps. DDVP is considered highly toxic to various fish and aquatic invertebrates species; however, the formulations and application method for DDVP use results in negligible risk to aquatic non-target organisms. Label requirements restricting use near water bodies and the lack of drift and runoff mitigate the risk to fish and aquatic invertebrates. The risk assessment demonstrates some risk to certain sensitive aquatic invertebrates based on an accidental scenario where a pest strip is dropped into the water. However, this risk estimate is conservative and any effects would be localized to individuals that are adjacent to the pest strip in the water. Risk to aquatic vertebrates, invertebrates, and plants is negligible for DDVP under normal use conditions and when used according to label directions.

## 1.0 INTRODUCTION

This human health and ecological risk assessment (HHERA) is a qualitative and quantitative evaluation of the potential risks and hazards to human health, non-target fish, and wildlife as a result of exposure to DDVP. DDVP is an organophosphate insecticide used to eradicate various species of exotic fruit flies (e.g., Mediterranean fruit fly, Mexican fruit fly, oriental fruit fly, etc.) that enter the United States. Organophosphate insecticides affect the functioning of the nervous system.

The methods used to assess potential human health effects follow standard regulatory guidance and methodologies (NRC, 1983; USEPA, 2016a), and generally conform to other Federal agencies such as the U.S. Environmental Protection Agency, Office of Pesticide Programs (USEPA/OPP). The methods used to assess potential ecological risk to non-target fish and wildlife follow USEPA and other published methodologies regarding eco-risk assessment.

The risk assessment is divided into four sections beginning with the problem formulation (identifying hazard), an effects analysis (the dose-response assessment), and an exposure assessment (identifying potentially exposed populations and determining potential exposure pathways for these populations). In the fourth section (risk characterization) the information from the exposure assessment and effects analysis are integrated to characterize the risk of applications to human health and the environment.

## 2.0 PROBLEM FORMULATION

Fruit flies in the family Tephritidae are among the most destructive and well-publicized pests of fruits and vegetables around the world. Exotic fruit flies in the genera *Anastrepha*, *Bactrocera*, and *Ceratitis* pose a great risk to U.S. agriculture. Tephritid fruit flies spend their larval stages feeding and growing on over 400 host plants. Introduction of these pest species into the United States causes economic losses from destruction and spoiling of host commodities, costs associated with implementing control measures, and loss of market share due to quarantines and restrictions on shipment of host commodities. The extensive damage and wide host range of tephritid fruit flies become obstacles to agricultural diversification and trade when exotic fruit fly species establish in these areas (USDA APHIS, 2013).

DDVP is an organophosphate insecticide. Organophosphate insecticides affect the functioning of the nervous system. DDVP is a potent cholinesterase (ChE) inhibitor via phosphorylation of the active site of the enzyme to cause neurotoxicity. DDVP exposure inhibits acetylcholinesterase (AChE) activity in brain, plasma, and red blood cells. AChE is an important enzyme for neurological function because the enzyme is necessary for the degradation of the neurotransmitter acetylcholine (ACh) and subsequent cessation of synaptic transmission. Inhibition of these enzymes causes the accumulation of ACh at cholinergic nerve endings and continual nerve stimulation, which can result in death. DDVP also binds to the active site of erythrocyte or red blood cell AChE and plasma butyryl ChE, resulting in reversible inhibition of these enzymes (USEPA, 2006a).

DDVP is registered for livestock, commercial, and residential uses including cattle, poultry, swine, agricultural equipment, feedlots, animal kennels, warehouses, mushroom houses, greenhouses, picnic areas, manure piles, refuse and solid waste sites, and residential dwellings (USEPA, 2009a). The target pests of DDVP include flies, gnats, mosquitoes, chiggers, ticks, cockroaches, armyworms, chinch bugs, clover mites, crickets, cutworms, grasshoppers, and sod webworms (USEPA, 2006a). DDVP formulations include pressurized liquid, granules, emulsifiable concentrate, total release aerosols, and impregnated materials. The application methods include aerosols, fogging equipment, spray equipment, and slow release from impregnated materials (e.g., resin strips) (USEPA, 2009b). The USDA-APHIS fruit fly eradication program uses DDVP-impregnated strips placed in traps with attractants (such as methyl eugenol or Cue-lure) to kill exotic fruit flies.

The following sections discuss the Chemical Description and Product Use; Physical and Chemical Properties; Environmental Fate; and Hazard Identification for DDVP.

### 2.1 Chemical Description and Product Use

DDVP (CAS No. 62-73-7,  $C_4H_7Cl_2O_4P$ ) is a phosphate triester with the common name of 2,2-dichlorovinyl dimethyl phosphate. The chemical structure is illustrated in figure 2-1.

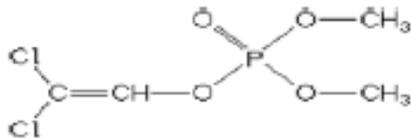


Figure 2-1 The chemical structure of DDVP

First registered in 1948, DDVP is the active ingredient in the trade names of Dichlorvos, DDVP, and Vapona (USEPA, 2006a). USDA-APHIS proposes to use the Hercon<sup>®</sup> Vaportape<sup>™</sup> II formulation (EPA Reg. No. 8730-50) (Hercon Environmental, 2016) or Plato Industries Insecticide Strip formulation (EPA Reg. No. 65458-5) (Plato Industries, Inc., 2013) in the fruit fly program. The Hercon<sup>®</sup> Vaportape<sup>™</sup> II formulation contains 10% DDVP, 0.75% DDVP-related compounds, and 89.25% other ingredients in 50 (1" x 4"), 500 (1" x ½"), or 100 (1" x ½") strips. The minimum net weights are 5.9 grams (g) for a 1" x 4" strip, and 0.7375 g for a 1" x ½" strip. The formulation is registered only for use in insect traps. The Plato Insecticide Strips contain 6.98% of DDVP, 0.52% of related compounds, and 92.50% of other ingredients in 1" x 1" square. Each square contains 0.09 g of active ingredient. The current recommendation is to use 0.09 g active ingredient in traps compared to higher doses (0.59 to 4.64 g active ingredient) that have been previously used in other types of traps (USDA APHIS, 2016).

## 2.2 Physical and Chemical Properties

DDVP is an oily, colorless to amber liquid, with an aromatic chemical odor. It has a molecular weight of 221 g/mole, and a boiling point of 117 °C at 10 millimeters of mercury (mmHg). DDVP is volatile with a high vapor pressure of 0.032 mmHg at 32 °C (0.012 mmHg at 20 °C). DDVP is soluble in water with a water solubility of 15,000 milligrams/liter (mg/L) at 25 °C. DDVP is miscible with aromatic hydrocarbons, chlorinated hydrocarbons, alcohols, ketones, and esters, and insoluble in kerosene and aliphatic hydrocarbons. DDVP has a low organic carbon coefficient (Koc) of 36.9 cubic centimeters (cm<sup>3</sup>)/g. The specific gravity of DDVP is 1.424 at 25 °C, and its octanol/water partition coefficient (Kow) is 38.4 (log Kow of 1.58). The measured Henry's Law constant of DDVP is 5.01 x 10<sup>-8</sup> atm-m<sup>3</sup>/mole at 25 °C (USEPA, 2006a).

## 2.3 Environmental Fate

The environmental fate describes the processes by which DDVP moves and transforms in the environment. The environmental fate processes include: 1) persistence and degradation, 2) mobility and migration potential to groundwater and surface water, and 3) plant uptake.

DDVP has low persistence in the environment. DDVP rapidly dissipates through volatilization, as well as through aerobic soil metabolism and abiotic hydrolysis. The half-life for an aerobic soil metabolism study was 10 hours with 2,2-dichloroacetic acid (DCA) and 2,2-dichloroethanol as the primary metabolites. Hydrolysis is pH dependent with reported half-lives of 11 days (pH

5), 5 days (pH 7), and 21 hours (pH 9) with DCA, 2,2-dichloroacetaldehyde, desmethyl dichlorvos, and glyoxylic acid as major degradates (USEPA, 2006a).

DDVP volatilizes to air and dissipates rapidly through volatilization under field conditions. Terrestrial field dissipation studies measured DDVP in the air above the field test plots at 89.2% (California) and 12.5% (Missouri) of the total applied DDVP after 2 hours (USEPA, 2009). The high vapor pressure indicates DDVP residues in food and environmental surfaces will dissipate rapidly. DDVP released in soil is moderately mobile (soil adsorption coefficients (Kd) ranging from 0.3 to 1.2). The high water solubility and low Koc for DDVP indicate a potential for offsite transport into surface and groundwater. DDVP is unlikely to leach to groundwater because of rapid degradation and its inability to establish soil/solution phase equilibrium. DDVP is not expected to be persistent in surface water because of its rapid degradation through hydrolysis and volatilization (USEPA, 2006a).

The bioaccumulation potential for DDVP is low based on the low Kow value of 33. DDVP hydrolyzes to dimethyl phosphate and dichloroacetaldehyde in plants, and is incorporated into natural plant constituents (USEPA, 2006a). The average dissipation half-life of DDVP in plants is 1.12 days with a range of 0.81 to 1.55 days (Fantke et al., 2014).

## **2.4 Hazard Identification**

Similar to other organophosphates, DDVP is toxic to mammals, including humans, through inhibition of the AChE(s) of the peripheral and/or central nervous system. Exposure to DDVP causes neurotoxicity and adverse respiratory and dermatologic irritant effects (USEPA, 2006a).

### **2.4.1 Toxic Effects**

Acute exposure to DDVP may cause headache, nausea, vomiting, diarrhea, abdominal cramps, anxiousness, restlessness, teary eyes, heavy sweating, salivation and tearing, constricted pupils, blurred vision, tightness in chest weakness, muscle twitching, and confusion (USEPA, 2006a, Hercon Environmental, 2014; Plato Industries, Ltd, 2007). Severe poisoning can cause coma, convulsions, inability to breathe, and death. Hematologic effects including aplastic anemia were reported with children's exposure to household insecticide products containing mixtures of insecticides including DDVP. However, the effects could not be definitively associated with DDVP exposure (USEPA, 2006a).

### **2.4.2 Metabolism**

DDVP is well absorbed through all routes of exposure, extensively metabolized, and excreted mostly in the urine as metabolic products and through exhalation as carbon dioxide. An esterase in plasma and liver inactivates the absorbed DDVP and catalyzes the hydrolysis of DDVP to form dimethyl phosphate and dichlorovinyl alcohol which spontaneously rearranges to 2,2-dichloroacetaldehyde to further metabolize. A glutathione-dependent reaction may also

inactivate DDVP to form desmethyl dichlorvos. DDVP has a short half-life of 15 minutes or less in the blood (USEPA, 2006b).

### **2.4.3 Human Incidents**

USEPA reviewed human-related incident reports (Blondell and Spann, 1998; USEPA, 2006a; USEPA, 2009b) for DDVP from the following public health databases:

- (1) the OPP incident data system (IDS), which contains anecdotal reports of incidents from various sources, including registrants, other federal and state health and environmental agencies, and individual consumers, submitted to OPP since 1992,
- (2) Poison Control Center Data for 28 organophosphate and carbamate chemicals for the years 1985 through 1992,
- (3) California Department of Food and Agriculture reports (superseded by the Department of Pesticide Regulation) that contain data on suspected pesticide poisonings collected since 1982, and
- (4) National Pesticide Telecommunications Network, a toll-free information service supported by OPP.

Amvac Chemical Corporation, the Japanese Resin Strip Manufacturer's Association, and two private citizens submitted additional poisoning incidents associated with DDVP (USEPA, 2006a).

USEPA's registration review of DDVP incident reports concluded poisoning incidents associated with DDVP exposure were reported for home and agriculture uses (USEPA, 2006a). The American Association of Poison Control Centers (AAPCC) reported 21,006 exposures to single products containing DDVP. However, the toxicities from these exposures cannot be solely attributed to DDVP because the single products with DDVP often contain other insecticides such as propoxur, pyrethrins, or piperonyl butoxide. The California data indicates that a majority of the incidents appear to involve worker illnesses (systemic illness including respiratory effects) from entering a facility previously fumigated with DDVP. DDVP exposures resulting in adverse effects are often from inadequate ventilation prior to allowing reentry in or near the treated area, or lack of proper personal protective equipment (PPE).

USEPA's reregistration review (2006a) indicated that DDVP resin strips were attributed to a small proportion of total incidents related to human exposure (about 33 cases per year or 1% of the total incidence reports). However, the incidents from resin strips usually did not involve any significant acute symptoms that required medical treatment. Two epidemiologic studies regarding home pesticide use (Davis, et al., 1993; Leiss and Savitz, 1995) indicated an association between exposure to DDVP resin strips and childhood cancer. The USEPA's review concluded the association between DDVP and childhood cancer is likely due to biases, and additional studies are needed to correct potential biases and problems with the exposure determination (USEPA, 2006a).

An updated USEPA review of OPP IDS on DDVP poisoning incidents occurring from 2000 to January 2009 found one case (USEPA, 2009b). However, the reported symptoms were generic

and not confirmed to be related to DDVP exposure. USEPA did not discern any remarkable case reports suggesting a plausible association between a moderate or severe health outcome and exposure to DDVP, or any suggestion of a trend or pattern regarding the health effects due to exposure to DDVP.

Tsai et al. (2014) identified 31 acute illness cases associated with the use of DDVP pest strips in seven U.S. States and Canada between 2000 and 2013. Among the reported cases, 26 persons had mild health effects of short duration with neurologic, respiratory, and gastrointestinal symptoms such as headache, dyspnea, and nausea. Five people had moderate health effects with symptoms including asthma, respiratory distress requiring hospitalization, paresthesias, and incoordination. The majority of these illnesses were caused by improper use of the product in occupied living areas with more than 4 hours exposure per day, which is inconsistent with label requirements.

#### **2.4.4 Acute Toxicity**

Technical active ingredient DDVP has high acute toxicity (Category I) via dermal exposure, and moderate acute toxicity (Category II) from oral and inhalation exposures. The dermal median lethal dose (LD<sub>50</sub>) values in rabbits are 75 milligrams/kilogram (mg/kg) (female) and 107 mg/kg (male). Oral LD<sub>50</sub> values in rats are 56 mg/kg (females) and 80 mg/kg (males). The inhalation median lethal concentration (LC<sub>50</sub>) in rats is ≥0.198 mg/L (4 hours). DDVP is a mild eye and skin irritant. There appears to be no data available for dermal sensitization (USEPA, 2006a).

Two separate acute oral cholinesterase inhibition studies in adult rats report a No Observed Adverse Effect Level (NOAEL) of 1 mg/kg, and a Lowest Observable Adverse Effect Level (LOAEL) of 2.1 mg/kg for erythrocyte and brain ChE inhibition. A third acute oral ChE inhibition study in adult rats reported a NOAEL of 1 mg/kg and a LOAEL of 5 mg/kg for erythrocyte and brain ChE inhibition (USEPA, 2006a).

A single oral dose study in young healthy male volunteers administered 70 mg of DDVP reported a NOAEL of 1.0 mg/kg body weight for red blood cell ChE depression based on the absence of biologically significant ChE depression. However, the first ChE measurement was recorded 24 hours after dosing in the study. The absence of biologically significant ChE depression may be due to absence of blood sampling within the peak effect time (1-3 hours) shown in a study in rats (USEPA, 2006b).

The Hercon<sup>®</sup> Vaportape<sup>™</sup> II formulation safety data sheet (Hercon Environmental, 2014) reported an acute dermal LD<sub>50</sub> values of 205 mg/kg in rabbits (Category II) for the active ingredient, and >5,050 mg/kg in rats (Category IV) for the formulation. The formulated material is an eye and skin irritant, and a possible skin sensitizer. The Hercon<sup>®</sup> Vaportape<sup>™</sup> II formulation has lower dermal toxicity compared to technical DDVP. The Plato Industries strip formulation safety data sheet (Plato Industries, Ltd., 2007) does not include any toxicity information for the formulation.

#### **2.4.5 Subchronic and Chronic Toxicity**

A 90-day subchronic oral study in rats reported a NOAEL of 0.1 mg/kg/day, and a LOAEL of 1.5 mg/kg/day based on plasma and red blood cell ChE inhibition (USEPA, 2006a).

A chronic feeding toxicity study in the dog reported a NOAEL of 0.05 mg/kg/day and a LOAEL of 0.1 mg/kg/day based on plasma and red blood cell ChE inhibition in both male and female dogs. USEPA used this study to develop a chronic oral reference dose (RfD) (see Section 3 for further discussion) (USEPA, 2006b).

A chronic inhalation toxicity study in rats reported a NOAEL of 0.00005 mg/L and a LOAEL of 0.0005 mg/L based on inhibition of plasma, red blood cell, and brain ChE activity (USEPA, 2006b).

During a repeated dose oral study, human volunteers were administered 7 mg of DDVP in corn oil (equivalent to approximately 0.1 mg/kg/day (d)) via capsule daily for 21 days. The study established a LOAEL at 0.1 mg/kg/d for red blood cell ChE inhibition depression (less than 20%, but consistent and statistically significant over time). The study did not establish a NOAEL (USEPA, 2006b).

#### **2.4.6 Nervous System Effects**

An acute oral neurotoxicity study in rats reported a NOAEL of 0.5 mg/kg and a LOAEL of 35 mg/kg based on changes in a neurotoxicity screening test, and decreased motor activity and body temperature with no neuropathology (USEPA, 2006a).

A 90-day subchronic oral neurotoxicity in rats reported a NOAEL of 0.1 mg/day and a LOAEL of 7.5 mg/kg/day for plasma, red blood cell, and brain ChE inhibition (USEPA, 2006b).

#### **2.4.7 Developmental or Reproductive Effects**

A developmental toxicity study in pregnant Sprague-Dawley rats (administrated DDVP (96.86% a.i.) at doses of 0, 0.1, 3.0, or 21.0 mg/kg/d by gavage) reported a NOAEL of 3.0 mg/kg/d for maternal toxicity, and a LOAEL of 21.0 mg/kg/d based on clinical signs of toxicity, reduced body weight gain, and food efficiency. The developmental NOAEL was 21.0 mg/kg/d, but a developmental LOAEL was not established. A developmental toxicity study in groups of pregnant New Zealand rabbits (orally administrated DDVP (97% purity) in distilled water at doses of 0, 0.1, 2.5, or 7.0 mg/kg/day) during gestation days 7 through 19 reported a maternal NOAEL of 0.1 mg/kg/d, and a maternal LOAEL of 2.5 mg/kg/d, based on maternal deaths and decreased body weight gain. No developmental toxicity was noted; therefore, the NOAEL was 7.0 mg/kg/d. The doses for this study were selected based on a range-finding study in rabbits with doses of 0, 0.1, 1.0, 2.5, 5.0, and 10.0 mg/kg/day. The range-finding study reported a ChE NOAEL of 0.1 mg/kg/d and a ChE LOAEL of 1.0 mg/kg/d based on maternal toxicity including

increased mortality and decreased weight gain. No effects were observed in the developmental studies in rats and rabbits (USEPA, 2006a).

A two-generation reproductive study in rats reported a parental/systemic NOAEL and LOAEL of 2.3 and 8.3 mg/kg/d, respectively. The LOAEL of 8.3 mg/kg/d was based on a decreased incidence of estrous cycling and increased abnormal cycling in F1 females, reduced water intake in both sexes, and decreased plasma and red blood cell ChE activity at all dosage levels in both sexes in both generations. In addition, brain ChE was decreased at 2.3 mg/kg/d in both sexes with a NOAEL of 0.6 mg/kg/day for brain ChE, and a NOAEL of less than 0.6 mg/kg/d for plasma and red blood cell ChE depression. The reproductive/offspring NOAEL/LOAEL were also 2.3/8.3 mg/kg/d. The LOAEL was based on a decrease in the number of dams bearing litters, reduced fertility indices, pregnancy index, and pup body weights on Day 4 of lactation in both F1 matings. Effects on ChE in offspring were not examined (USEPA, 2006a).

There is no concern for pre- and/or postnatal toxicity resulting from DDVP exposure because there is no evidence for increased susceptibility of the rat and rabbit offspring to prenatal or postnatal exposure to DDVP. USEPA (2006a) determined there are no residual concerns for increased susceptibility of infants and children.

#### **2.4.8 Carcinogenicity and Mutagenicity**

USEPA classifies DDVP as having “suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential” (USEPA, 2015; 2006a). The classification was based on an increased incidence of forestomach tumors in female mice and mononuclear cell leukemia in male Fischer 344 rats (a two-year inhalation carcinogenicity study). However, USEPA’s Scientific Advisory Panel and cancer experts with the National Toxicology Program and Health Effects Division’s Cancer Assessment Review Committee have classified DDVP as “suggestive” and not requiring quantitation of cancer risks because of the following: 1) mononuclear cell leukemia in the male Fischer rat has certain properties regarding variability and reliability that limit its usefulness for humans; 2) the forestomach tumors in mice observed at gavage doses causing inhibition of plasma and red blood cell ChE and cholinergic signs are limited in their application to humans; and 3) the forestomach tumors in mice observed using gavage exposures (not inhalation route, the major route of human exposure), and the localized effects in the forestomach from the oral route may not be applicable to humans (USEPA, 2006a).

Some epidemiologic investigations in farm workers suggest a potential effect of DDVP on prostate cancer (Mills and Yang, 2003; Alavanja et al., 2003), leukemia (Brown et al., 1990), and non-Hodgkin lymphoma (Cantor et al., 1992). However, an evaluation by the Agricultural Health Study cohort found little evidence of association between exposure to DDVP and the incidence of cancer (Koutros et al., 2008). The cohort study evaluated 1,180 prostate cancer cases (the previous study had 566 prostate cancer cases) and observed a small risk associated with exposure among those with a family history of prostate cancer. There was no evidence of an increased risk of leukemia and non-Hodgkin lymphoma associated with DDVP exposure.

DDVP is a direct acting mutagen in some common *in vitro* bacterial genetic toxicity assays and in *in vitro* mammalian test systems, and may induce *in vivo* mutagenicity via oxidative stress. DDVP seems to also have clastogenic activity by inducing chromosomal aberrations, sister chromatid exchanges, and polyploidy in cultured Chinese hamster ovary cells *in vitro*; however, there was conflicting evidence for clastogenic activity in *in vivo* micronucleus tests (USEPA, 2006a).

#### **2.4.9 Endocrine System Effects**

DDVP is on the list of Endocrine Disruptor Screening Program (EDSP) universe of chemicals for endocrine disruptor screening and testing (USEPA, 2012a). The EDSP list is not a list of “known” or “likely” endocrine disrupting chemicals (USEPA, 2012b). DDVP was screened using the ToxCast™ "Endocrine Receptor Model" for estrogen receptor bioactivity as a pesticide active ingredient (USEPA, 2016b). The screening results for DDVP showed no estrogen receptor bioactivity. Based on the available toxicity studies, DDVP has no estrogen, androgen, and/or thyroid mediated toxicity.

#### **2.4.10 Immune System Effects**

The USEPA registration review of DDVP does not address immune system effects (USEPA, 2006a). The submitted DDVP toxicity studies showed no effects on the immune system (USEPA, 2009b). An immunotoxicity study for DDVP (Guideline 870.7800) in rats reported a NOAEL of 15 mg/kg/d without the establishment of a LOAEL for immunotoxicity (USEPA, 2012c). The study also reported a systemic toxicity NOAEL of 0.1 mg/kg/d and a LOAEL of 1.2 mg/kg/d based on marked reduction of erythrocyte and brain AChE activity.

A literature review indicated that some household insecticides containing DDVP may be associated with some immunological effects (USEPA, 2007). However, the effects were associated with mixtures of pesticides and not DDVP alone.

#### **2.4.11 Toxicity of Other Ingredients**

Approximately 89.25% of the Hercon® Vaportape™ II and the Plato Industries Insecticide Strips are other ingredients (Hercon Environmental, 2016; Plato Industries, Inc., 2013). However, neither the labels nor the safety data sheets include specific information on the other ingredients (Hercon Environmental, 2014; Plato Industries, Ltd., 2007).

## 3.0 DOSE-RESPONSE ASSESSMENT

### 3.1 Human Health Dose-Response Assessment

A dose-response assessment evaluates the dose levels (toxicity criteria) for potential human health effects including acute and chronic toxicity.

The USEPA/OPP established an acute Reference Dose (RfD) of 0.008 mg/kg/d for the general population using a benchmark dose (BMD) approach, which is a preferable alternative to the NOAEL/LOAEL approach (USEPA, 2006b). The estimated dose resulting in 10% inhibition of ChE (BMD<sub>10</sub>) for DDVP in rats is 1.6 mg/kg, and the lower 95% confidence limit on the BMD<sub>10</sub> (BMDL<sub>10</sub>) is 0.8 mg/kg. The acute RfD for DDVP was derived by applying an uncertainty factor of 100 (10x for interspecies extrapolation, and 10x for intraspecies variation) to the BMDL<sub>10</sub> of 0.8 mg/kg based on female brain ChE depression. The additional special Food Quality Protection Act (FQPA) factor is not needed because there are no substantial numerical differences in the acute BMDL values (approximately 1 mg/kg) based on the BMD analysis of pup and adult ChE depression results for either red blood cell or brain ChE inhibition (USEPA, 2006a, b).

For short term residential and occupational exposure (30 days or less), the RfD for all routes of exposure is based on the 21-day repeated dose study in humans with a LOAEL for red blood cell ChE inhibition of 0.1 mg/kg/d. The uncertainty factor is 30 (10x for intraspecies variability and a FQPA safety factor of 3x due to lack of a NOAEL) (USEPA, 2006b).

The USEPA/OPP also derived a chronic oral RfD of 0.0005 mg/kg/d for a chronic oral exposure scenario for all populations. The chronic RfD was developed by applying an uncertainty factor of 100 to the NOAEL of 0.05 mg/kg/day based on plasma and red blood cell ChE inhibition in males and females at 0.1 mg/kg/d (LOAEL) from a one-year chronic dog study. An uncertainty factor of 100 was selected based on 10x for interspecies variation, 10x for intraspecies extrapolation, and 1x for a FQPA factor (USEPA, 2006a). For dermal exposure, USEPA estimated a dermal absorption rate of approximately 11% in 10 hours of DDVP exposure based on a dermal absorption study in rats (USEPA, 2006a).

USEPA/OPP classified DDVP as “Suggestive Evidence of Carcinogenicity, but Not Sufficient to Assess Human Carcinogenic Potential”. However, USEPA is not requiring quantitative estimates of cancer risk for DDVP due to the lack of relevance of the identified tumors (mononuclear cell leukemia in male Fischer 344 rats and the forestomach tumors in mice) to humans. In addition, DDVP is only positive for tumors by oral exposure and was negative by the inhalation route, which is the primary route of human exposure (USEPA, 2006a).

USEPA has established tolerances for DDVP on agricultural (food and feed) crops and animal commodities (40 CFR 180.235). The tolerances for cucumbers, lettuce, mushrooms, and tomatoes are expressed as naled (USEPA, 2006a). There are no DDVP tolerance levels established for fruits.

## 3.2 Ecological Dose-Response Assessment

### 3.2.1 Wild Mammal, Avian and Reptile Toxicity

The acute and chronic toxicity of DDVP to wild mammals is characterized in section 2.4 of this risk assessment. In general, DDVP is classified as moderately to highly toxic in oral, inhalation, or dermal acute exposures.

DDVP is considered highly toxic to birds based on available acute oral toxicity data (table 3-1). DDVP is considered moderately to practically non-toxic to birds in subacute dietary exposures (table 3-2).

Table 3-1. Acute oral toxicity of DDVP to various avian test species.

Test Organism	LD <sub>50</sub> (mg/kg)	Reference
Mallard, <i>Anas platyrhynchos</i>	7.78	USEPA, 2005
Northern bobwhite quail, <i>Colinus virginianus</i>	8.8	USEPA, 2005
Domestic fowl, <i>Gallus domesticus</i>	6.3*	Mohammad et al., 2008
Pheasant, <i>Phasianus colchicus</i>	11.3	USEPA, 2005
Red-winged blackbird, <i>Agelaius phoeniceus</i>	13.3	Schafer et al., 1983
European starling, <i>Sturnus vulgaris</i>	11.0	Schafer et al., 1983

\*24 hour LD<sub>50</sub> value using 7–15 day old chicks

Table 3-2. Subacute dietary toxicity of DDVP to various avian test species.

Test Organism	LC <sub>50</sub> (mg/kg)	Reference
Mallard, <i>Anas platyrhynchos</i>	1317 - >5000	USEPA, 2005
Japanese quail, <i>Coturnix japonica</i>	300	WHO, 1989
Pheasant, <i>Phasianus colchicus</i>	568	USEPA, 2005
Domestic fowl, <i>Gallus domesticus</i>	500	WHO, 1989

Sublethal effects have also been evaluated in subchronic and chronic exposure studies using various bird test species. ChE inhibition is a biomarker of organophosphate and carbamate insecticide exposure. Sublethal exposures to these insecticides can result in physiological (thermoregulation, reduced food consumption, reproduction) and behavioral (predator avoidance) effects to vertebrates (Grue et al., 1997). Mohammad et al. (2008) measured 49 and 59% inhibition in plasma and brain ChE inhibition, respectively, in 24-hour exposures using domestic fowl chicks. In a 28-day delayed neurotoxicity study in hens a NOAEL of 0.1 mg/kg/d and a LOAEL of 0.3 mg/kg/d using brain ChE inhibition with no neuropathology was reported

(USEPA, 2006a). Two chronic avian reproductive toxicity studies are available in dietary exposures using DDVP (USEPA, 2005). In the first study using the mallard, a NOEC and LOEC of 5 and 15 parts per million (ppm), respectively, were reported based on several reproductive endpoints such as egg shell thickness, eggs laid, viable embryos, and live three week embryos. In the second study using the northern bobwhite quail, *Colinus virginianus*, the NOEC and LOEC was reported as 30 and 100 ppm, respectively. Endpoints affected included eggs laid, viable embryos, normal hatchlings, and 14-day old survivors.

Little data exists regarding DDVP toxicity to reptiles. No oral or dietary dosing studies appear to be available, however, there have been DDVP studies assessing ChE inhibition in the lizard, *Gallotia galloti*. These studies have low ecological relevance because in the first study they collected blood from lizards to dose in the lab *in vitro* to evaluate AChE and butylcholinesterase (BChE) activities (Sanchez-Hernandez and Sanchez, 2002). The other study evaluated similar enzyme endpoints and evaluated the same enzyme activities in field-collected specimens (Sanchez-Hernandez, 2003). There was inhibition of ChE activity in field-collected lizards from agricultural areas; however, it was after exposure to various carbamate and organophosphate insecticides. Therefore, no cause and effect relationship with DDVP exposure could be established.

Dosing in the above mentioned mammal, avian, and reptile studies was carried out using a liquid formulation of DDVP. No dosing studies were available using DDVP in the proposed formulation for the exotic fruit fly eradication program. Toxicity would be expected to be less than the liquid formulations because not all DDVP would be available for absorption in the vapor tape formulation.

### **3.2.2 Terrestrial Invertebrate Toxicity**

DDVP is considered highly toxic to many terrestrial invertebrates due to its broad spectrum activity. Toxicity to pollinators such as honey bees is high with oral and contact median lethality values typically below 1 microgram ( $\mu\text{g}$ )/bee (WHO, 1989; USEPA, 2016c). Stanley et al. (2015) documented high mortality to *Apis mellifera* and *A. cerana* at label-recommended doses of DDVP. These studies were carried out using the emulsifiable concentrate formulation. DDVP has also been shown to be highly toxic to butterflies and moths. Hoang and Rand (2015) observed larval butterfly 24-hour dietary LD<sub>50</sub> values of 0.206, 0.327 and 1.959  $\mu\text{g/g}$  body weight for the atala hairstreak (*Eumaeus atala*), common buckeye (*Junonia coenia*), and white peacock (*Anartia jatrophae*), respectively. High toxicity was also observed for the same species in adult contact toxicity studies with 24-hour LD<sub>50</sub> values of 1.63, 11.30 and 1.48  $\mu\text{g/g}$  body weight for the atala hairstreak, common buckeye, and white peacock, respectively (Hoang et al., 2011).

### 3.2.3 Terrestrial Plant Toxicity

No data appears to be available in the literature regarding the effects of DDVP to terrestrial plants. Toxicity would be expected to be low in cases where exposure could occur due to the mechanism of action of DDVP and the proposed formulation that would eliminate the potential for significant exposure.

### 3.2.4 Aquatic Vertebrates Toxicity

DDVP is considered moderately to highly toxic to fish in acute exposures. Median lethality values using the technical active ingredient range from 200 µg/L for the lake and cutthroat trout, to 12,000 µg/L for the fathead minnow (table 3-3).

Table 3-3. Acute aquatic toxicity of DDVP to freshwater and marine fish test species.

Test Organism	LC <sub>50</sub> (mg/L)	Reference
Lake trout, <i>Salvelinus namaycush</i>	0.2	Johnson and Finley, 1980
Cutthroat trout, <i>Oncorynchus clarkii</i>	0.2	Johnson and Finley, 1980
Striped mullet, <i>Mugil cephalus</i>	0.23	WHO, 1989
Mosquito fish, <i>Gambusia affinis</i>	5.3	Johnson and Finley, 1980
Bluegill, <i>Lepomis macrochirus</i>	0.9	Johnson and Finley, 1980
Rainbow trout, <i>Oncorynchus mykiss</i>	0.5	USEPA, 2005
Sheepshead minnow, <i>Cyprinodon variegatus</i>	7.3	USEPA, 2005
Carp, <i>Cyprinus carpio</i>	9.4	Ural and Calta, 2005
Fathead minnow, <i>Pimephales promelas</i>	12.0	Johnson and Finley, 1980

Sublethal impacts to fish from DDVP exposures have been noted in acute and chronic exposures. Sisman (2010) reported decreased swimming activity for the zebrafish in 96-hour exposures to 25 mg/L DDVP. No effects on swimming activity were observed at 10 mg/L. Chronic toxicity is also high for fish exposed to DDVP. USEPA (2005) report a NOEC and LOEC of 5.2 and 10.1 µg/L, respectively, in an early life stage study using the rainbow trout. A chronic exposure using the marine fish, sheepshead minnow, report a NOEC and LOEC of 960 and 1,840 µg/L, respectively (USEPA, 2005).

Available DDVP toxicity data for amphibians demonstrate a comparable range of sensitivities as fish in acute exposures. Geng et al. (2005) reported 96-hour LC<sub>50</sub> values of 51.64, 10.53, 12.94, and 0.78 mg/L for *Bufo melanostictus*, *Fejervarya multistriata*, *Polypedates megacephalus*, and *Mycrohyla ornata*, respectively. Exposures were conducted using tadpoles in the 25–26 Gosner stage of development.

### 3.2.5 Aquatic Invertebrates Toxicity

Aquatic invertebrates are more sensitive to DDVP than aquatic vertebrates based on acute exposures. Median lethality and effective concentrations range from 0.07 to 89,100 µg/L with freshwater invertebrates being more sensitive than marine invertebrates (table 3-4).

Table 3-4. Acute aquatic toxicity of DDVP to select freshwater and marine aquatic invertebrates.

Test Organism	LC <sub>50</sub> (µg/L)	Reference
Cladoceran, <i>Daphnia pulex</i>	0.07	USEPA, 2005
Cladoceran, <i>Simocephalus serrulatus</i>	0.26	USEPA, 2005
Stonefly, <i>Pteronarcys californica</i>	0.1	Johnson and Finley, 1980
Amphipod, <i>Gammarus lacustris</i>	0.5	Johnson and Finley, 1980
Mysid, <i>Americamysis bahia</i>	19.1	USEPA, 2005
Eastern oyster, <i>Crassostrea virginica</i>	89,100	USEPA, 2005

Chronic toxicity to aquatic invertebrates from DDVP exposure is also high. USEPA (2005) reported a NOEC and LOEC of 0.0058 and 0.0122 µg/L, respectively, for the freshwater cladoceran, *Daphnia magna* in a 21-day exposure. Egg production and growth were the endpoints affected. In another chronic exposure study using the mysid shrimp, a NOEC and LOEC of 1.48 and 3.25 µg/L, respectively, were reported in a 21-day exposure (USEPA, 2005). Weight and length were the endpoints affected.

### 3.2.6 Aquatic Plants Toxicity

Aquatic plant toxicity data for DDVP is limited to four studies that show low toxicity to most species. USEPA (2005) reported 48-hour median effective concentration (EC<sub>50</sub>) values of 78, 14, and greater than 100 mg/L for a species of green algae, an unknown species of algae and a marine diatom, respectively. Yeh and Chen (2006) reported 48-hour EC<sub>50</sub> values of 0.737 mg/L and 1.616 mg/L based on dissolved oxygen and cell production, respectively, using the green algae, *Pseudokirchneriella subcapitata*.

## 4.0 EXPOSURE ASSESSMENT

### 4.1 Human Health Exposure Assessment

The exposure assessment estimates the potential exposure of humans to DDVP. The exposure assessment begins with the use and application method for DDVP in the exotic fruit fly eradication program. A complete exposure pathway for DDVP includes (1) a release from a DDVP source, (2) an exposure point where contact can occur, and (3) an exposure route such as ingestion, inhalation, or dermal. In this way, the potentially exposed human populations and complete exposure pathways are identified. Finally, exposures for the identified human populations are qualitatively or quantitatively evaluated for each exposure pathway.

#### ***4.1.1 Identification of Potentially Exposed Human Populations and Complete Exposure Pathways***

APHIS uses DDVP-impregnated Vapor II strips (2.5 x 10 cm, 2 mm thick, 0.58 g DDVP) in a closed trap, or a Plato Industries Insecticide Strip (1" x 1", 0.09 g DDVP) in an open trap to attract and kill exotic fruit flies (Shelly et al., 2015). The strips in the traps are replaced after 5 or 12 weeks or when effectiveness diminishes (Plato Industries, Inc., 2013, Hercon Environmental, 2016). The traps are placed on tree trunks and limbs at 1,000 per square mile in a 1.5 mile radius from each fruit fly detection site. Based on the application method, workers in the program are the most likely human population segment to be exposed to DDVP. Occupational exposure to DDVP may occur through inhalation and dermal contact with this compound during application (placing the strips in the traps). However, dermal contact exposures are minimized because no mixing is required and the label requires PPE such as gloves. Inhalation exposure is minimized because workers assemble the traps outdoors. Drift from the application is not expected because DDVP is impregnated in strips placed inside the traps. Therefore, exposure to workers should be negligible under normal conditions. Accidental exposure to a DDVP strip may occur during trap assembly for a worker. This accidental exposure scenario is further quantified in the next section.

The general public (e.g., residents) is not recognized as a potentially exposed population group due to public notification about exotic fruit fly eradication activities and the method of application which would eliminate off-site movement of DDVP from drift or runoff. APHIS and its cooperators will notify residents about placing traps on their property.

A complete exposure pathway associated with direct contact to DDVP strips from the trap application is not identified for the general public. Based on the proposed use pattern of DDVP in the exotic fruit fly eradication program, the potential for the general public to be exposed to DDVP is not expected via inhalation from ambient air, ingestion of food and drinking water, or dermal contact. Volatilization of DDVP occurs in a trap, however, the exposure potential is low due to the small quantities used in the trap and the placement of the trap outdoors. Exposure to DDVP in traps through direct contact by a child is not expected because families would be notified of surveys, and the traps will be placed out of the normal reach of children. However, if

traps were accidentally dislodged, there could be potential exposure mainly via dermal contact and incidental ingestion through hand-to-mouth contact with the DDVP strip. The accidental exposure for a child is further quantified in the next section.

A complete exposure pathway is not identified for dietary consumption of fruit from fruit bearing trees because DDVP within traps is not applied directly to plants and fruits.

A complete exposure pathway is not identified for the groundwater medium because the formulation proposed by the program is a strip impregnated with a small amount of DDVP. The potential for DDVP in a strip to release to soil is low. Even if a small amount of DDVP is accidentally released to soil, DDVP rapidly degrades and is unlikely to leach into groundwater (see Section 2.3).

A complete exposure pathway is not identified for the surface water medium. Significant surface runoff is not expected to occur from the program application of the strip formulation based on program and label requirements, as well as DDVP's rapid degradation and volatilization. Drift is not expected to be a concern for the strip formulation. DDVP has a low K<sub>oc</sub> value and high water solubility suggesting it could move to surface water, but the method of application and low Henry's law constant eliminates the potential for any significant runoff. In addition, the label states not to apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark.

#### **4.1.2 Exposure Evaluation**

This section qualitatively evaluates worker exposure from direct contact pathways while handling DDVP strips based on program use, and quantitatively evaluates accidental dermal exposure to a DDVP strip during trap assembly by a worker. Accidental dermal exposure to a child (pre-teenager ages 10 to 12 years) from a dislodged trap is also quantitatively evaluated. Use of the DDVP strips in the program occurs when flies are determined to be in the area and trapping and fruit fly delimitation takes place. Exotic fruit fly treatments vary temporally and spatially from year to year. The duration for a typical eradication is normally two to three months.

Exposure for workers is expected to be negligible from the use of an impregnated strip inserted into a trap. No dilution or mixing is required for the product. The DDVP-impregnated strips are sealed in a protective pouch to be opened when ready to be placed in a trap. The label requirements include not opening the protective pouch until ready for use. Both the Hercon<sup>®</sup> Vaportape<sup>™</sup> II and the Plato Industries pest strips are to be used only as a toxicant strip for outdoor insect traps (Hercon Environmental, 2016, Plato Industries, Inc., 2013). The strips are replaced every 5 or 12 weeks or when effectiveness diminishes. Direct contact to DDVP during application is not expected to occur when following label directions or as specified in the safety data sheets (Hercon Environmental, 2014, 2016, Plato Industries, Inc., 2013). Under normal use of Hercon<sup>®</sup> Vaportape<sup>™</sup> II, PPE such as respiratory protection, eye protection, and protective

gloves are not required except for vinyl, latex, or rubber gloves are recommended for continuous handling. The Plato Industries pest strips label (Plato Industries, Inc., 2013) requires coveralls over short-sleeved shirt and short pants, chemical-resistant footwear plus socks, and chemical-resistant gloves made of waterproof material for applicators and handlers. The occupational exposure limit (8 hour time weighted average) for DDVP is 1 mg/m<sup>3</sup> (the Occupational Safety and Health Administration permissible exposure limit (PEL)) and 0.1 mg/m<sup>3</sup> (the American Conference of Governmental Industrial Hygienists threshold limit value (TLV)). A PEL is the level to protect workers against the adverse effects of exposure to a chemical. A TLV is the limit of exposure to a chemical workers can be exposed to daily without adverse health effects.

Accidental exposure from dermal contact may occur for workers during trap assembly if gloves are torn or punctured. Although DDVP exposure concentrations are expected to be low because only small amounts (0.58 g or 0.09 g in a strip) are used in each trap, accidental dermal exposure to a DDVP strip is quantitatively evaluated. The upper and lower ends of dermal exposure were quantified based on the two types of strips proposed in the program. When gloves are torn, it is possible that the tips of the fingers and perhaps other areas of the hand may contact a DDVP strip. However, it is the program practice to use the packaging to hold the strip as it is being placed and hand contact directly never occurs if done properly. To quantify the accidental dermal exposure, each fingertip area was assumed to have an area of 1 square centimeter (cm<sup>2</sup>), and the thumb was assumed to have an area of 2 cm<sup>2</sup>. Thus, the total surface areas of the fingertips of both hands are 12 cm<sup>2</sup>. The surface area is assumed to be 24 cm<sup>2</sup> to account for the potential contact to other parts of the hand. Total contact time with the strip was assumed to be 30 minutes. A dermal absorption rate of 0.0009 cm/hour was assumed based on a U.S. Forest Service estimation of dermal permeability for the Vapor II DDVP strips (US FS, 2004). The assumptions used in this exposure scenario led to estimated absorbed doses of 0.004 mg/kg/d to 0.002 mg/kg/d for the two types of strips (appendix A, A-1).

Accidental dermal and inhalation exposure to DDVP strips from a dislodged trap may occur for a child (pre-teenager ages 10 to 12 years). Inhalation exposure for this scenario is not a concern because traps are placed outdoors. The amount of DDVP (0.58 g or 0.09 g) for fruit fly eradication is lower than the level of DDVP (0.975 g) in a pest strip for use in a cupboard of a household. The more conservative exposure values from household use also showed no concern for 24-hour inhalation exposures in an enclosed space (USEPA, 2006a). For the accidental dermal exposure, the exposed skin surface area is assumed to be the dimensions of the strip (25 cm<sup>2</sup> or 6.45 cm<sup>2</sup> for the two types of strips). Similar to the worker exposure scenario the total contact time with the strip was assumed to be 30 minutes. A dermal absorption rate of 0.0009 cm/hour was assumed in the calculation (US FS, 2004). The assumptions used in this exposure scenario led to estimated absorbed doses of 0.006 mg/kg/d to 0.001 mg/kg/d for the two types of strips (appendix A, A-2).

## **4.2 Ecological Exposure Assessment**

### **4.2.1 Terrestrial Exposure Assessment**

The proposed formulation of DDVP suggests that exposure to non-target vertebrates and invertebrates are expected to be low. The use of DDVP strips in traps will mitigate potential dietary exposure of DDVP for terrestrial vertebrates. Removal of traps by a scavenging small mammal that could be exposed to DDVP has not been noted in previous trapping efforts during exotic fruit fly outbreaks. In the case that a small mammal contacted a trap it would be highly unlikely that it would consume the strip due to its composition. Inhalation and dermal exposure would also be low because the strip is contained within the trap. Due to the low probability of contact with the strip formulation of DDVP, the exposure is not quantified.

Non-target terrestrial invertebrate exposure is not quantified because exposure will be primarily to exotic fruit flies due to the use of the trap in combination with the fruit fly attractant. Any non-target invertebrate exposure would be incidental and not expected to be significant for any group of terrestrial invertebrates other than the target pest.

### **4.2.2 Aquatic Exposure Assessment**

Aquatic exposure from DDVP use in the exotic fruit fly eradication program is unlikely. The strips that contain DDVP are inserted by hand into the traps; therefore, drift would not occur. Runoff also will not be a significant exposure pathway because strips that fall to the ground would not be expected to be carried as runoff to a receiving water body. Current label requirements state that the strips should not be used in areas where water bodies are present or to intertidal areas below the mean high water mark, further reducing the potential for aquatic exposure.

As a means of quantifying potential residues, an assumption was made that a strip could be accidentally dropped into a water body. The upper bound value of 0.58 g DDVP in a strip was used to determine the quantity of DDVP that could occur in a wetland and pond. Not all of the DDVP in the strip would be in solution because DDVP is released slowly over time from the strip. U.S. Forest Service (2004) reported using a value of 30% as the quantity of DDVP that could be released during a 24-hour period. The value was based on a study that evaluated the amount of DDVP that was released in a 24-hour period from a pest strip when exposed to gastric juices. The USEPA standard pond and wetland dimensions were used to estimate DDVP values in both water bodies. Acute instantaneous residues in the wetland and pond habitats ranged from 0.02 to 0.28 µg/l, respectively. The estimates assume uniform distribution of DDVP in both static water bodies and that no degradation or dissipation of DDVP would occur once in solution. Estimates for residues in flowing streams and larger water bodies would be much less due to higher dilution.

## 5.0 RISK CHARACTERIZATION

### 5.1 Human Health

Risks associated with potential adverse human health effects are characterized qualitatively and quantitatively in this section. Results from the risk characterization suggests that the use of DDVP will pose minimal risks to human health for all population segments.

Worker risk to DDVP via oral, inhalation, and dermal routes is expected to be minimized by adherence to label requirements including the use of PPE. DDVP is a hazard to humans because of its acute ChE depression toxicity from ingestion, inhalation, and dermal contact. However, the low potential for significant exposure by using DDVP in a pest strip suggests minimal risk.

Risk from DDVP exposure to the general public is also minimal due to its use in the form of a pesticide strip, the notification process for placing traps, and the lack of exposure that would occur from drinking water. Risks from the ingestion of treated food would also not be anticipated because DDVP used in traps would not come into contact with fruit. In addition, fruits within the treated areas are destroyed as part of the integrated exotic fruit fly eradication program. The risk associated with children touching the DDVP strips in traps is low because traps are placed out of the normal reach of children.

The risks associated with the accidental exposure for a worker from dermal contact to a DDVP strip during trap assembly, and a child (pre-teenager ages 10 to 12 years) from dermal contact to a dislodged trap, were estimated using hazard quotients (HQs) that were calculated using the following USEPA risk estimation equation for non-carcinogens:

$$\text{HQ} = \text{Exposure (Dose)} / \text{Reference Dose}$$

The calculation results for a worker and child are summarized in table 5-1. The acute reference dose of 0.008 mg/kg/d was used because an accidental exposure would be considered an infrequent occurrence.

Table 5-1. Risk Summary Associated with Accidental Exposure for a Worker and a Child

Exposure Scenario	Hazard Quotient	
	Upper Estimate	Lower Estimate
<b>Accidental Dermal Exposure</b>		
Worker	0.4	0.3
Child (Pre-teenager ages 10 to 12 years)	0.7	0.1

HQ values that exceed 1.0 suggest that there may be a risk to a specific group of the population while values below 1.0 suggest that risk is minimal. Table 5-1 shows hazard quotients associated

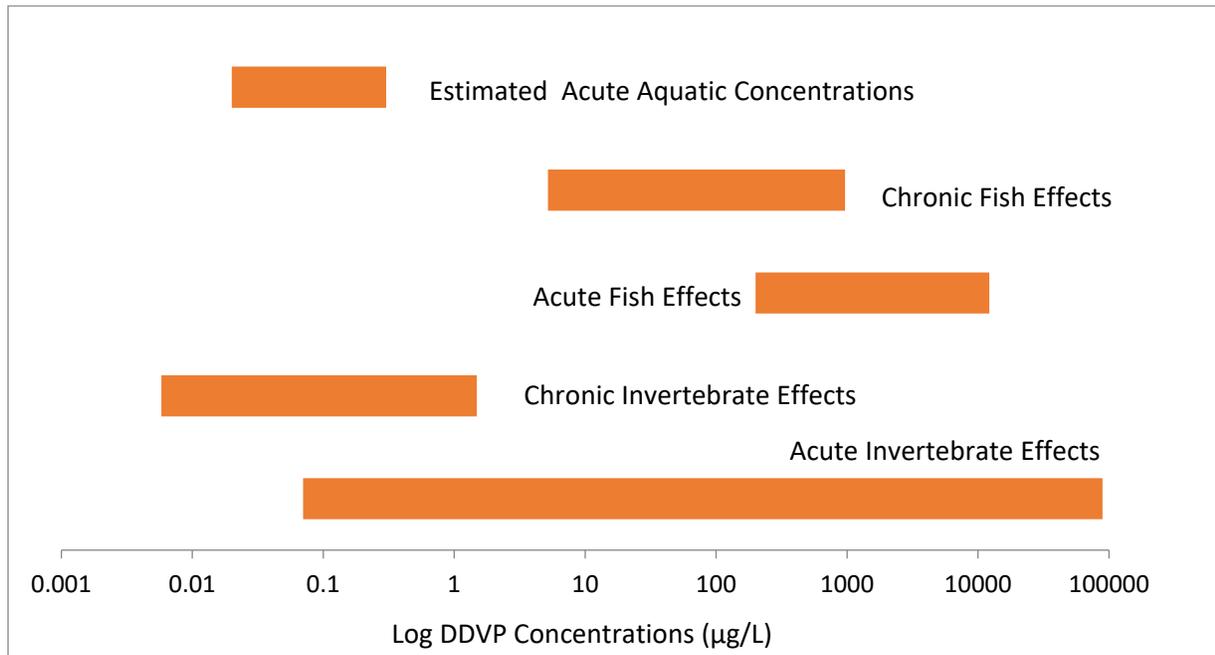
with accidental dermal exposure are below 1.0 for workers and children. Detailed calculations are included in appendix A.

## **5.2 Terrestrial and Aquatic Risk Characterization**

The lack of significant exposure to terrestrial vertebrates from DDVP applications in the exotic fruit fly eradication program suggests negligible risk to this group of non-target organisms. Similarly, there is a lack of significant exposure to non-target terrestrial invertebrates due to the formulation of DDVP, and its use in traps in combination with a fruit fly lure. DDVP is toxic to pollinators such as honey bees and butterflies; however, the lack of significant exposure due to the use pattern reduces the risk to these groups of invertebrates. There is the possibility of some risk for terrestrial invertebrates that may come into contact with the strip; however, these effects would be incidental and localized to individual traps.

Risk to aquatic vertebrates and invertebrates is also expected to be negligible. Conservative assumptions regarding exposure to fish when compared to the range of acute and chronic effects demonstrate wide margins of safety (figure 5-1). The range of estimated aquatic residues in static, small water bodies was one to three orders of magnitude below the range of acute and chronic toxicity endpoints. Aquatic invertebrates are more sensitive to the effects of DDVP when compared to fish and some sensitive aquatic invertebrates may be at risk from DDVP exposure based on the overlap between the estimated residues and the range of acute and chronic effects. The risk would be expected to be greatest for those sensitive aquatic invertebrates that are adjacent to the pest strip. The risk characterization in this exercise did not assume any degradation of DDVP, which in aquatic systems is very rapid due to hydrolysis, suggesting that chronic risks would be low to aquatic invertebrates. Risks to aquatic plants that may serve as food and habitat for aquatic vertebrates and invertebrates are also negligible based on the available toxicity data for aquatic plants, and the conservative residue estimates in small, static water bodies.

Figure 5-1. Aquatic risk characterization for DDVP.



## 6.0 UNCERTAINTIES AND CUMULATIVE IMPACTS

The uncertainties associated with this risk evaluation arise primarily from limited information about the effects of DDVP, its formulations, metabolites, and potential mixtures to non-target organisms that can occur in the environment. These uncertainties are not unique to this assessment but are consistent with uncertainties in HHERAs with any environmental stressor. In addition, there is uncertainty about locations where exotic fruit fly detections may occur in the United States, and the extent of DDVP use in a given infestation because its use is based on site-specific factors.

Another area of uncertainty is the potential for cumulative impacts to human health and the environment from the proposed use of DDVP in exotic fruit fly eradication programs. Areas where cumulative impacts could occur are: 1) repeated worker and environmental exposures to DDVP from program activities in conjunction with other crop use sources; and 2) co-exposure to other chemicals with a similar mode of action.

Approximately 54% of the annual uses of DDVP in the United States were for commodities in bulk storage, distribution warehouses, and processing plants; 28% were for livestock and poultry; and 15% were for pest control operator/structural use (USEPA, 2006a). Publicly available data from the California Department of Pesticide Regulation show that the DDVP amounts used in California over the three most recent years available (2004–2006) were 3807.15 pounds (lbs), 4,898.19 lbs, and 6,527.38 lbs, respectively (CADPR, 2008). The APHIS exotic fruit fly eradication program use of DDVP during limited fruit fly outbreak cases per year is much less compared to normal agriculture use (approximately 0.58 g or 0.0002 lb (0.09 g) DDVP used in each trap).

DDVP is the degradation product of naled and trichlorfon (two other organophosphate pesticides) in food, water, or the environment (USEPA, 2009c). Naled is also used in the fruit fly eradication program. Cumulative impacts may occur from DDVP use in relation to other chemicals used in the program that have a similar or different mode of action, and can result in synergism, potentiation, additive, or antagonistic effects. The potential for co-exposure to other pesticides within the program or outside the program with the same toxic action may also occur. The other pesticides used in the fruit fly eradication program include spinosad, lambda-cyhalothrin, diazinon, and malathion. Spinosad over-activates the central nervous system of insects via the nicotinic acetylcholine receptors. Lambda-cyhalothrin disrupts normal nerve function by inhibiting the closing of the voltage-gated membrane sodium channels of nerve cells. Naled, diazinon and malathion are also organophosphate pesticides with the same mode of action as DDVP. The results of USEPA's Organophosphate Cumulative Risk Assessment (2006c) represent exposure and risk from food, water, and residential use to the U.S. population, and support a reasonable certainty of a no harm finding as required by the FQPA. Not all of these products would be used at the same time in one place to treat an outbreak. All of the program insecticides have multiple other uses that could occur in areas where fruit fly treatments may occur. The spatial and temporal variability in these other uses relative to treating sporadic exotic

fruit fly outbreaks make it difficult to quantify cumulative impacts from the additional use of program insecticides. However, cumulative impacts from the proposed use of DDVP is expected to be incrementally minor due to the proposed use pattern, adherence to individual pesticide label requirements for risk mitigation measures, and the historical low frequency of exotic fruit fly detections in the United States.

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## Appendix A

### A-1. Accidental Dermal Exposure Assessment for a Worker Contacting a DDVP Strip During Assembling a Trap

Parameter/Assumption	Equation			Reference/Rational
	Values	Units		
Receptor	Worker			
Duration	Acute			
The amount of DDVP in a strip	Upper	580	Mg	Vapor II strip Plato Industries Insecticide Strip
	Lower	90	Mg	
Surface area of a strip	A	25	cm <sup>2</sup>	2.5 cm x 10 cm (Vapor II strip) 2.54 cm x 2.54 cm (Plato Industries Insecticide strip)
<b>The amount of DDVP per cm<sup>2</sup></b>	<b>Amnt</b>	<b>6.45</b>	<b>cm<sup>2</sup></b>	<b>The amount of DDVP in a strip/A</b>
	Upper	23.2	mg/cm <sup>2</sup>	
	Lower	13.95	mg/cm <sup>2</sup>	
Exposed skin surface area (hand)	SA	24	cm <sup>2</sup>	US FS, 2004
Exposure duration	ED	0.5	hour/day	Reasonable assumption
Event	EV	1	event/day	Reasonable assumption
Body weight	BW	70	kg	USEPA, 2006a
<b>Absorbed Dose</b>	<b>(Amnt x DP x SA x ED x EV)/BW</b>			
	Upper	0.0035794	mg/kg/day	
	Lower	0.0021523	mg/kg/day	
Acute Reference Dose	aRfD	0.008	mg/kg/day	USEPA, 2006a
<b>Risk</b>	<b>Absorbed Dose/aRfD</b>			
	Upper	<b>0.4</b>		
	Lower	<b>0.3</b>		

**A-2. Accidental Dermal Exposure Assessment for a Child Contacting a DDVP Strip**

Parameter/Assumption	Equation		Units	Reference/Rational
	Values			
Receptor	Pre-Teen (10-12 years old)			
Duration	Acute			
The amount of DDVP in a strip	Upper	580	mg	Vapor II strip
	Lower	90	mg	Plato Industries Insecticide Strip
Surface area of a strip	A	25	cm <sup>2</sup>	2.5 cm x 10 cm (Vapor II strip)
		6.45	cm <sup>2</sup>	2.54 cm x 2.54 cm (Plato Industries Insecticide strip)
<b>The amount of DDVP per cm<sup>2</sup></b>	<b>Amnt</b>	<b>The amount of DDVP in a strip/A</b>		
	Upper	23.2	mg/cm <sup>2</sup>	
	Lower	13.95	mg/cm <sup>2</sup>	
Dermal permeability	DP	0.0009	cm/hour	US FS, 2004
Exposed skin surface area (hand)	SA	25	cm <sup>2</sup>	the dimensions of the strip, US
		6.45	cm <sup>2</sup>	FS, 2004
Exposure duration	ED	0.5	hour/day	Reasonable assumption
Event	EV	1	event/day	Reasonable assumption
Body weight	BW	44	kg	USEPA, 2011, Table 8-1, Average of the recommended values for Body Weight between Ages 6 to <11 years and 11 to <16 years.
<b>Absorbed Dose</b>	<b>(Amnt x DP x SA x ED x EV)/BW</b>			
	Upper	0.00593	mg/kg/day	
	Lower	0.00092	mg/kg/day	
Acute Reference Dose	aRfD	0.008	mg/kg/day	USEPA, 2006a
<b>Risk</b>	<b>Absorbed Dose/aRfD</b>			
	Upper	<b>0.7</b>		
	Lower	<b>0.1</b>		