Planning and Standard Operating Procedures for the Use of Rotenone in Fish Management

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Rotenone SOP Manual, 2nd Edition

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Planning and Standard Operating Procedures for the Use of Rotenone in Fish Management

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Rotenone SOP Manual, 2nd Edition*

American Fisheries Society
Fish Management Chemicals Committee

Brian Finlayson, *Co-Chair*†, Don Skaar, *Co-Chair*,
Jon Anderson, Julie Carter, Dan Duffield, Mark Flammang,
Chad Jackson, Joe Overlock, Jarle Steinkjer, and Roger Wilson

*The applicator is responsible for conforming to the product labeling, including this manual and all applicable laws and regulations. This manual provides guidance on the safe and effective application of rotenone and is intended for the use of fish biologists and fishery managers in the United States and Canada. The manual is available from the registrants or American Fisheries Society at www.rotenone.fisheries.org. SOPs may be revised or new SOPs may be added and approved by the EPA in the future, and applicators should check the AFS website frequently for changes.

†Author to whom correspondence should be submitted:
Brian Finlayson
2271 Los Trampas
Camino, CA 95709
briankarefinlayson@att.net

American Fisheries Society
425 Barlow Place
Bethesda, Maryland 20814
USA

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Top Left: An applicator spraying the bank area of a tributary to Bob White Lake, Iowa with rotenone for removal of Common Carp in 2015 (photo credit: Mark Flammang).

Top Right: Students from the AFS rotenone training class at Utah State University take flow measurements in preparation for a mock treatment of Temple Fork, Logan River in 2016 (photo credit: Brian Finlayson).

Bottom Right: Applicator calibrating a dripcan used to treat the Rondegat River, South Africa with rotenone for removal of Smallmouth Bass in 2013 (photo credit: Bruce Ellender).

Bottom Left: Treatment of Diamond Lake, Oregon with rotenone for removal of Tui Chub in 2006 (photo credit: Brian Finlayson).

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American Fisheries Society
425 Barlow Place, Suite 110
Bethesda, Maryland 20814
USA

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Preface

Rotenone was first used as a piscicide in the United States and Canada in the 1930s. Prior to the passage of the amendment to the Federal Insecticide, Rodenticide and Fungicide Act of 1970, rotenone and other pesticides were regulated in the United States by the U.S. Department of Agriculture, and rotenone was first registered in 1947. In 1970, pesticides became regulated by the U.S. Environmental Protection Agency. Registration now requires physical, chemical, public health, and environmental data to demonstrate effectiveness at appropriate concentrations of the intended use and to allow for assessments of risk estimating the impacts to human health and the environment. In 1988, all pesticides, including rotenone, registered before November 1, 1984 were put into a reregistration process requiring the generation of data to support continued registration. After the necessary risk assessments for rotenone were completed, the U.S. Environmental Protection Agency issued the Reregistration Eligibility Decision in March 2007 (EPA 738-R-07-005). As a condition of the reregistration requirements, a manual was requested by EPA that contained procedures, specifically on how to minimize nontarget exposure and effects and to provide guidance on the label directions. With the approved reregistration came several significant technical changes in how rotenone will be used as a tool in fish management. These changes are incorporated into Standard Operating Procedures (SOPs) in the Manual that provide guidance on how to comply with the label and use rotenone in a safe and effective manner. The American Fisheries Society's Fish Management Chemicals Committee, in cooperation with the rotenone registrants and the U.S. Environmental Protection Agency, developed the 2nd edition.

The Manual contains four chapters, beginning with an introduction that orients the reader to a brief history of rotenone registration, label directions, use as a fish management tool, information on formulations and environmental fate, toxicity to fish and wildlife, public health and concerns, product stewardship, and an overview of the manual structure. The second chapter provides general guidance on rotenone project planning procedures and how the Standard Operating Procedures are used in successful planning. The third chapter contains a summary of various sampling techniques used to monitor the biotic and abiotic components of the aquatic environment. The fourth chapter contains Standard Operating Procedures that complement the label. The Manual is considered labeling and must be present along with the label at the project site, and it is a violation of Federal law to use rotenone in a manner inconsistent with its labeling including both the product label and the Manual. Detailed instruction on rotenone application and deactivation techniques, public and environmental safety, environmental fate and effects, and chemistry and toxicology and matching rotenone formulations to specific waters and examples of successful planning are provided in a week-long course given by the Manual's authors using this Manual as the course textbook. The Manual and information on current piscicide course scheduling can be found at the American Fisheries Society's website www.fisheries.org/membership/continuing-education/.

It is important that the user carefully study and fully understand the label and the AFS Rotenone SOP Manual. When in doubt, the user should contact the manufacturer or their state pesticide regulatory agency. SOPs may be revised or new SOPs may be added and approved by the EPA in the future. Applicators should check the AFS website www.rotenone.fisheries.org frequently for changes.

Common Abbreviations and Glossary of Terms

Absorption = movement of rotenone treated water or product into solid media such as the skin or eyes

Adsorption = movement of rotenone onto the surface of solid media such as sediment

AF = acre feet; surface acre of water one foot deep

AFS = American Fisheries Society

a.i. = active ingredient rotenone in liquid or powdered commercial formulations

atm = atmosphere; used in Henry's Law constant as a measure of the solubility of a gas in liquid

BCF = bioconcentration factor; the potential for a substance to accumulate in living biological tissue (tissue rotenone concentration ÷ water rotenone concentration)

Bioassay = an in-situ test in the rotenone treated and deactivated water to determine its toxicity (see SOP 14.1) to fish or a toxicity test using varying concentrations of rotenone on target fish to establish their sensitivity (i.e., LC_{50} value) for treatment purposes (see SOP 5.1).

CAS = Chemical Abstracts Service

Certified Applicator = Federal law requires that any person who applies or supervises the application of a Restricted Use Pesticide such as rotenone be certified under EPA regulations and state, territorial, or tribal laws. The term Certified Applicator is used synonymously in this manual with Qualified Applicator.

CFR = Code of Federal Regulations

CHCP = Comprehensive Hazard Communication Plan required by OSHA's Hazard Communication Standard.

CWA = Clean Water Act

Deactivation = the processes of hydrolysis, photolysis, metabolism, and chemically induced oxidation with potassium permanganate ($KMnO_4$) that degrades rotenone to an undetectable concentration (<2 ppb). This process has been previously referred to as detoxification, neutralization, and degradation (see SOP 7.1).

Deactivation Zone = The area (length) of stream beginning at the point where $KMnO_4$ is added to the stream discharge to the point downstream where rotenone has been deactivated to an undetectable concentration (<2 ppb rotenone). The travel time of water in the deactivation zone moving between these two points is normally 30 minutes (see SOP 7.1).

EA = environmental analysis

EPA = U.S. Environmental Protection Agency

Eradication = elimination of whole fish populations or fish species from distinct habitats or bodies of water

ESA = Endangered Species Act

FIFRA = Federal Insecticide, Fungicide and Rodenticide Act

FMCC = Fish Management Chemicals Committee of the American Fisheries Society

FMP = Fish Management Plan

FS = Forest Service of the U.S. Department of Agriculture

FWS = Fish and Wildlife Service of the U.S. Department of the Interior

HCS = Hazard Communication Standard required by OSHA provides employees with the identities and hazards of chemicals to which they are exposed

ICS = Incident Command System

Ingestion = swallowing treated water or product

Inhalation = breathing volatile product vapors and dust

K_d = partition coefficient for rotenone adsorption in sediment
(rotenone adsorbed ÷ rotenone at equilibrium)

K_{oc} = organic carbon normalized partition coefficient for sediment
[(K_d • 100) ÷ organic content (%)]

K_{ow} = octanol-water partition coefficient is the solubility of rotenone in water and solvent
[log (rotenone octanol solubility ÷ rotenone water solubility)]

MATC = maximum acceptable toxicant concentration = $(NOEC \bullet LOEC)^{1/2}$

MED = minimum effective dose roughly equal to twice the LC_{50} value

NEPA = National Environmental Policy Act

NFPA = National Fire Protection Association ratings of fire hazards

NIOSH = National Institute of Occupational Safety and Health ratings of safety equipment

NOAA = National Oceanic and Atmospheric Administration of the U.S. Department of Commerce

NPDES = National Pollutant Discharge Elimination System

OSHA = Occupational Safety and Health Administration or Act

PIS = Primary Irritation Score in ocular toxicity studies

Project Area = The Project Area typically includes (1) the Treatment Area (see *Treatment Area*) and surface water and ground water that are hydrologically connected to the Treatment Area and affected by the rotenone application, (2) the Deactivation Zone (see *Deactivation Zone*) in flowing water where rotenone treated water is chemically deactivated with $KMnO_4$ to undetectable (<2 ppb rotenone) levels, and (3) other areas affected by the Treatment Area operations that may include staging areas, areas receiving drift and project crew activity. The Project Area is not defined on the label but is a useful demarcation of the impacted area for which effects may be assessed (see SOP 6.1).

ppb = parts per billion; equivalent to 1/1000 ppm (0.001 x ppm), µg/L and µg/kg

PPE = personnel protective equipment used to mitigate for the four possible routes of pesticide exposure.

RED = Reregistration Eligibility Decision

Rotenone = active ingredient in the rotenone formulation (product)

Rotenone Formulation (Product) = the product from the manufacturer including the active ingredient rotenone and inert ingredients

RUP = Restricted-Use Pesticide; requires its use to be by or under the direct supervision of a Certified Applicator.

SDS = Safety Data Sheet required by OSHA and used as part of the CHCP

Service Container = a container (i.e., drip can or backpack sprayer), other than original product container, that is approved for rotenone storage and contains (1) name and address of person or entity responsible for the container, (2) identity of the pesticide in the container and (3) signal word from the original container.

Signal Word = a rating of the acute health hazard of a pesticide on its label that ranges from “Danger” (Toxicity Category I or extremely harmful) to “Warning” (Toxicity Category II or moderately harmful) to “Caution” (Toxicity Category III).

SOP = Standard Operating Procedure

$t_{1/2}$ = half-life; the time period in which half of an amount of substance dissipates; also referred to as DT_{50} (time for 50% dissipation).

Toxicity Category = see *Signal Word*

Treatment Area = The portion of the Project Area where rotenone is applied as a means of control or eradication of the target species (see SOP 6.1).

Undetectable Rotenone = The concentration of rotenone in water that is less than (<) the analytical detection limit of 0.002 ppm (see SOP 16.1).

USDA = U.S. Department of Agriculture

1 Introduction

Fisheries biologists rely on a wide variety of methods for the management and assessment of fish populations to maintain diverse and healthy aquatic ecosystems and high quality recreational fisheries. One of the most valuable tools is the botanical piscicide rotenone, which was first used in the United States in 1934 (Ball 1948; Lennon et al. 1971; Cumming 1975) and in Canada in 1937 (M'Gonigle and Smith 1938). Rotenone is a product of the bean family that has been used for centuries by native peoples from Southeast Asia and Central and South America in the collection of fish for food (Ling 2003).

The *Rotenone SOP Manual 2nd edition* is designed to provide fishery managers and others with procedures needed for carrying out restoration projects with rotenone in an effective and safe manner while meeting existing laws and regulations of all regulatory jurisdictions. The authors and reviewers of the manual represent a wide range of knowledge and experiences in using rotenone from several federal and state natural resource agencies throughout the United States and Norway.

1.1 Registration, Label Directions, and SOPs

Over the past several decades, the use of rotenone has become a concern to a variety of interests including environmental and animal rights groups (Williams 2004; Finlayson et al. 2005). The American Fisheries Society (AFS) recognized a need to respond to increased concerns and established the "Rotenone Stewardship Program" in 1993. In 2000, AFS used U.S. Fish and Wildlife Service (FWS) Division of Federal Aid administrative funds to prepare and produce a manual on rotenone use for fisheries managers entitled, *Rotenone Use in Fisheries Management—Administrative and Technical Guidelines Manual* (Finlayson et al. 2000). The first edition of the *Rotenone SOP Manual* (Finlayson et al. 2010) was a revision and expansion of the 2000 manual because the U.S. Environmental Protection Agency (EPA) (2007) required it as part of the reregistration process for rotenone. The current 2nd edition incorporates further technical and regulatory developments in rotenone use that have occurred since the 1st edition was published in 2010.

Adhering to the rotenone formulation (product) label and the *Rotenone SOP Manual* will result in the safe and effective use of rotenone for fish management while reducing the risks and providing adequate protection for public health and the environment. Rotenone is classified as a Restricted Use Pesticide and as such, the Certified Applicator is responsible for ensuring that all applicable laws, regulations, and label instructions are followed.

A number of changes have been made to the use of rotenone during the last decade. In summary, the changes (with corresponding SOPs or Chapters if applicable) are:

- **Project Supervision and Safety**—All applications must be supervised by a Certified Applicator who is required to remain on site until the treatment is completed, and he/she should receive training and have certain qualifications (SOPs 2.1 and 3.1). The personal protective equipment (PPE) requirements for powder and liquid formulations are different. The PPE requirements are constantly in flux so check the product label you are using for the correct equipment.

- **Maximum Rotenone Treatment Levels**—The maximum treatment concentration in standing and flowing waters is 200 ppb rotenone (4 ppm 5% a.i. formulation). For all applications, the selected treatment rate is based on the response of target fish (or surrogate species) in a bioassay with site water (or in similar water quality) within the maximum level on the label (SOP 5.1).

- **Re-entry Requirements**—For treatment concentrations that are >90 ppb rotenone (≥1.8 ppm 5% a.i. formulation), reentry after the completion of the treatment without PPE, with the exception of

respirators, is not allowed until levels decline to <90 ppb rotenone (SOP 1.1). The length of time the area remains placarded is dependent on the treatment levels. Technical information on rotenone analysis is provided (SOP 16.1).

- **Monitoring Requirements for Treating Drinking Waters**—For treatment levels that are >40 ppb rotenone (≥0.8 ppm 5% a.i. formulation), the Certified Applicator must inform drinking water users 7 to 14 days prior to treatment against the consumption of treated water (SOP 16.1). Technical information on sampling waters for biological impacts (Chapter 3) and the interaction of surface and ground waters (SOP 16.1) are provided.

- **Application of Rotenone**—All powdered rotenone (with the exception of the powder-gelatin-sand mixture in SOP 13.1) formulations require the use of a semi-closed system for application (SOP 9.1) and are not allowed in lotic environments. Similar application equipment is required for applying undiluted liquid rotenone from original product containers (SOP 8.1). The systems employ aspirator probes that are inserted into a bung hole of the drum with a snug fit and the undiluted product is removed using suction created by a pump. Rotenone is generally applied below the surface, but liquid formulations may be applied to the surface of the water with backpack sprayers, drip cans, broadcast applicators, or hand-held or hand-directed spray nozzles (SOPs 11.1, 12.1, and 13.1).

- **Strategies for Fish Removal**—Strategies have been developed for both the eradication and partial control of target fish (SOP 5.1).

- **Treatment of Upwelling Groundwater**—New techniques have been developed for treating springs, seeps, upwelling groundwater, and areas of poor water exchange (SOP 13.1).

- **Transferring Liquid Rotenone**—Transferring liquid rotenone from original product containers to service containers or other application devices is made in a plastic-lined, bermed area or other secondary containment area capable of recovering any spilled product as described (SOP 10.1).

- **Rotenone Use in Marine/Estuarine Environments**—The use of rotenone in marine/estuarine environments is not allowed.

- **Chemical Deactivation of Treated Flowing Water**—The flow of a stream or outflow of a treated lake beyond the treatment area requires chemical deactivation with potassium permanganate (SOP 7.1) when rotenone concentrations are >2 ppb. The deactivation zone and other areas affected by the treatment are included in the definition of a project area (SOP 6.1).

- ***Rotenone SOP Manual***—This *Rotenone SOP Manual* was mandated by EPA and is provided for guidance on the safe and effective use of rotenone and to assist in following the label. The manual is considered product labeling, should be consulted prior to treatment, and kept at the project site.

Only when rotenone is used according to the label is there a presumption that no unreasonable effects are expected to occur to humans or the environment. Thus, using rotenone in a manner inconsistent with its label is a violation of Federal and State laws. Violations may result in criminal penalties (up to a $5,000 fine and six months in jail per violation) when there has been an intentional or gross negligent misuse, or civil penalties (up to $25,000 per violation) or administrative remedies (revocation of license) when there has been an unintentional misuse. This manual provides guidance, but when in doubt, Certified Applicators should consult with their state or local pesticide control agency.

1.2 Fish Management Tool

Fisheries managers rely on a wide variety of tools for the management and assessment of fish populations to maintain diverse and healthy aquatic ecosystems and quality recreational fisheries. One of these tools is rotenone, which has been used for centuries to capture fish for food in areas where these plants are naturally found (Ling 2003). By 1949, 34 states and several Canadian provinces were using rotenone routinely for the management of fish populations (Solman 1950; Lennon et al. 1971). The piscicide was applied first to ponds and lakes, and then to streams by the early 1960s for either complete or partial reclamation (Schnick 1974). Rotenone was initially used in various powdered forms until emulsifiable formulations were developed that acted faster and were easier to handle and dispense, especially in lotic environments.

A number of methods have been used for removing fish from aquatic habitats including the broad-spectrum piscicide rotenone. Compared to agricultural and home use pesticides like malathion and glyphosate, the annual use of rotenone is considered minor, averaging about 7,500 kg a.i. per year (McClay 2000; 2005). Rotenone has been used throughout North America without serious incident for over 75 years (McClay 2000; 2005), and its use is supported by the Association of Fish and Wildlife Agencies and Trout Unlimited. Rotenone is registered for use by or under permit from, and after consultation with State and Federal Fish and Wildlife and/or Natural Resource Agencies.

Fisheries managers may decide to use rotenone when fish communities have been disrupted by human activities (e.g., physical manipulations of natural waters, effects of pollution on natural production of fish species, demand for recreational fisheries, and introduction of exotic species into surface waters). The primary reasons for rotenone use have changed over the years. Originally, rotenone was mainly used to control undesirable fish populations so that sport fish could be stocked and managed for recreational purposes in lakes, ponds, and streams without competition, predation, or other interference by the undesirable fish (Lennon et al. 1971; McClay 2000). But increasingly, rotenone is used to eradicate invasive fish and restore native, threatened and endangered species of fish, amphibians, and invertebrates (McClay 2000; 2005).

Certain fish are considered undesirable and may need to be removed because they impact desired fish through (a) competition, (b) predation, (c) genetic introgression, (d) harboring disease organisms, or (e) altering habitats (Krueger and May 1991; Ross 1991). Competition with nonnative salmonids has been implicated in the decline of many native inland salmonid species (Allendorf 1991; Krueger and May 1991; Finlayson et al. 2005). Predation on native fish has also been provided as a reason for removing fish, including the Northern Pikeminnow *Ptychocheilus oregonenis* (Zimmerman and Ward 1999), Green Sunfish *Lepomis cyanellus* (Lemly 1985), Smallmouth Bass *Micropterus dolomieu* (Weyl et al. 2014), Lake Trout *Salvelinus namaycush* (Kaeding et al. 1996), and Northern Pike *Esox lucius* (California Department of Fish and Game 1991; 1997; 2007; Massengill 2014). Native fish stocks may be exposed to diseases that were not historically present in habitats occupied by native stocks (Krueger and May 1991). For example, Baltic Sea stocks of Atlantic Salmon *Salmo salar* are immune to the monogenean trematode parasite *Gyrodactylus salaris*, but it is fatal to indigenous Northern Sea stocks in Norway (Johnsen 2006). Direct genetic effects include crosses between species that result in sterile hybrids and crosses that lead to introgression (Krueger and May 1991; Finlayson et al. 2005). Bronmark and Edenhamn (1994) suggested that rotenone might be an appropriate tool for removing introduced fish populations from previously fishless streams of Sweden to conserve populations of tree frogs *Hyla arborea*, and rotenone was used in Lake Haussmann at the Lawrence Livermore National Laboratory for successful eradication of several introduced fish species in recovery efforts for the California Red-Legged Frogs *Rana aurora draytonii* (Campbell and Rueppel 2006).

Intentional and unintentional introductions have made fish one of the world's most introduced groups of aquatic animals (Gozlan et al. 2010). Nonnative fish introductions have had impacts on genetic, individual, population, community, and ecosystem levels in recipient environments (Cucherousset and Olden 2011) through competition, predation, habitat alteration, disease, and hybridization interactions (Moyle 2002; Clarkson et al. 2005). Active intervention of introduced fish species that have invaded and threatened biodiversity is usually required to restore a native ecosystem. Success of eradication is considered high if the invasive species is caught soon after invasion when the population and distribution are low; success

is proportionately less with increased numbers and distribution over time (Kolar et al. 2010). Unless all introduced fish or disease-infected fish are removed, they are able to reproduce and the problem continues.

As noted above, rotenone has been increasingly used to eradicate invasive alien species and fish diseases (Uzmann and Douglas 1966; McClay 2000; 2005; Johnsen 2006; Vasquez et al. 2012; Finlayson et al. 2014) and conserve and restore native species (Behnke 1992; Knight et al. 1999; McClay 2000, 2005; Finlayson et al. 2005; Weyl et al. 2014). Nonchemical methods are available for fish control and suppression and are typically lower cost with higher public acceptance, but their collective limitation is that these usually, by themselves, don't result in eradication (Table 1.1). Although most methods will afford some level of control, empirical evidence suggests that with the exception of dewatering, piscicides are generally required for complete removal of a target species (i.e., eradication) from a waterbody. Dewatering is often technically and socially impractical and unattainable. Intense and numerous manual/physical removal efforts over four to five years may be successful in removing target fish from simple alpine aquatic habitats (i.e., stream and lake margins free of aquatic macrophytes, suspended sediment, woody debris, large cobble, undercut banks, and overhanging riparian vegetation) (Pacas and Taylor 2015). However, piscicides provide the greatest chance for success, and successful eradication may require the application of several techniques applied in concert (i.e., rotenone for eradication and fish management structure to prevent reinvasion).

Eradication using piscicides was more successful than other control efforts for improving desirable aspects of a fishery (Meronek et al. 1996). Rotenone is the most widely used piscicide in the USA, and its toxicity to fish has been well documented (Marking and Bills 1976; McClay 2000; 2005; Finlayson et al. 2009). Marking et al. (1983) evaluated several chemicals as tools for preventing the invasion of non-indigenous fish species into Canada and found that rotenone was the most effective of the eight chemicals tested. Exposure times and rates necessary to kill fish vary by species and water temperature, and use instructions require that the rotenone formulation be tested with the target species in the site water to determine the treatment rate and duration.

1.3 Formulations

Rotenone ($C_{23}H_{22}O_6$), or (6R, 6aS, 12aS)-1,2,6,6a,12,12a-hexahydro-2-isopropenyl-8,9-dimethoxychromenyl[3,4-bfuro[2,3-h]chromen-6-one, is a botanical pesticide registered for piscicidal (fish kill) uses (Figure 1.1). Rotenone (CAS 83-79-4) is a flavonoid found in roots, seeds, and leaves of various plants that are members of the bean family Leguminosae from Australia, Oceania, southern Asia, and South America. Other plant flavonoids (rotenoloids) that are similarly structured to rotenone are also contained in the plants from which rotenone is extracted. Formulated end-use products of rotenone may have varying amounts of "cube root extractables" containing rotenoloids. Cubé resin extracted from plants contains rotenone, deguelin, rotenolone (metabolite of rotenone), and tephrosin (metabolite of deguelin) (Fang and Casida 1999), but the toxicity is almost entirely due to rotenone content and not the other 25 plus flavonoids (Fang et al. 1997). Analytical standards are available from several research chemical suppliers (e.g., Aldrich and Sigma) and the registrants.

Rotenone products are classified as Restricted Use Pesticides (RUP) due to acute inhalation, acute oral, and aquatic toxicity. Rotenone is formulated as a powder (ground-up plant root material) or extracted from plants as liquid and formulated with emulsifiers and solvents for use as a piscicide (Ball 1948; McClay 2005). Rotenone powder is typically packaged in 50- to 250-pound cardboard containers, and rotenone liquids are typically packaged in 1-, 5-, 30- and 50-gallon plastic and metal jugs and drums. Applications are generally made with boats in lakes, reservoirs, and ponds. Direct metering into moving water such as streams occurs using drip cans and with hand-held equipment such as backpack sprayers in difficult to reach areas, isolated pools, and other non-mixing areas. Rotenone may be applied at any time of year, but most applications typically occur during warm months because the compound is more effective and degrades more rapidly in warm water than cold water.

Table 1.1. Advantages and disadvantages of various fish control methods.

Control Method	Advantages	Disadvantages
Angling Regulations	Publicly acceptable, allows harvest of fish, and less fish waste	Slow, angling pressure often inadequate, and many species not vulnerable
Nets and Electrofishing	Publicly acceptable and can allow for more selective removal	Unlikely to eradicate fish and could harm native fish
Biological	May be low cost and good management alternative	Limited success, unpredictable results, and inability to control species; concerns with pathogens and legal requirements
Dewatering Lake	May be low cost and allows for less use of chemical	Water remains in pools, detrimental to game fish, and often environmentally disruptive
Physical Barriers to Fish Movement	Downstream barriers must remain in place to have long-term advantages	Not effective for downstream migration, less effective under floods, high cost, isolated populations, and unpopular with public
Explosives	Low cost and effective in small areas	Impact dam integrity, hazardous to humans and non-target organisms, unlikely to be permitted in or near critical habitat for endangered species
Stream Flow Reduction	Publicly acceptable and easy implementation	Water rights issues, multiple-use conflicts

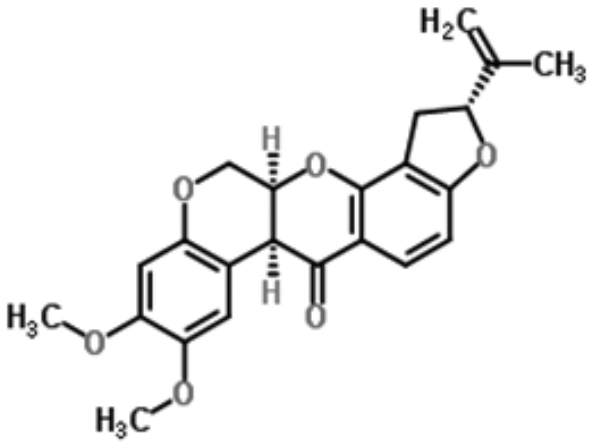

Figure 1.1. Structure of rotenone.

1.4 Environmental Fate

Rotenone has low to moderate mobility in soil and sediment (K_d = 3.6–194), has a relatively low potential for bioconcentrating in aquatic organisms (BCF < 30), is not persistent in the environment (due to hydrolysis and photolysis) with half-lives measured in days and hours, respectively, and its low vapor pressure (6 x 10^{-6} Pa) and Henry's Law constant (estimated 1.1 x 10^{-13} atm–m^3/mol) limit volatility (Table 1.2). Confirming the low volatility of rotenone, an air monitoring study in California failed to detect rotenone in air surrounding applicators during several spray applications of liquid rotenone formulation CFT Legumine (Westervelt 2007). Rotenone degrades quickly through abiotic and biological mechanisms with residues generally persisting from a day to several weeks in temperate environments (Finlayson et al. 2001; Vasquez et al. 2012; Finlayson et al. 2014). Rotenone can persist for many months in colder northern environments (Gilderhus et al. 1988; Massengill 2014; Stensli and Bardal 2014).

At the rotenone concentrations typically used, the target fish are killed within hours of application provided that treatment concentrations are maintained at relatively constant levels for sufficient duration. Treatment concentrations are designed to exceed the median lethal concentrations (LC_{50} value) by several-fold to assure complete kills of the target fish. Rotenone degrades at least moderately rapidly in aquatic

Table 1.2. Physical and chemical properties of technical rotenone.

Property	Value	Reference
Molecular weight	394.4 g/mol	Tomlin (1994)
Melting point	157–175ºC	Huntingdon Life Sciences (2007)
log K_{ow}	3.59	Huntingdon Life Sciences (2007)
Water solubility (20°C)	0.296 mg/L	Huntingdon Life Sciences (2007)
Vapor pressure (25°C)	6 x 10^{-6} Pa	Huntingdon Life Sciences (2007)
Henry's Law constant	1.1 x 10^{-13} atm–m^3/mol	EPIWIN (2004)—estimate
Hydrolysis $t_{½}$ (25°C)	12.6 days (pH 5) 3.2 days (pH 7) 2.0 days (pH 9)	Thomas (1983)
Aqueous photolysis $t_{½}$	8.2 hours	Draper (2002)
Photolysis $t_{½}$ [a]	2.9 hours	Cheng et al. (1972)
Sediment partition coefficient (k_d)	3.6 (sand) 194 (silty loam)	Dawson (1986)
BCF (fish)	10.8 (viscera) 27.9 (head) 27.6 (whole carcass)	Gingerich and Rach (1985)

[a]Estimated from rotenone applied to the surface of bean leaves.

environments, thus it is unlikely that residues will accumulate and persist for long periods in water or sediment. Rotenolone is the major metabolite from hydrolysis (Thomas 1983). Water treated with rotenone will generally detoxify through natural dissipation processes within one week to one month, depending upon environmental conditions. In the USA, Gilderhus et al. (1988), Vasquez et al. (2012), and Finlayson et al. (2001, 2014) found dissipation half-life (DT_{50}) values for rotenone in impoundments to vary from <1 to 10 days, inversely related to temperature and pH values.

1.5 Toxicity to Fish and Wildlife

The direct application of 25 to 200 ppb rotenone (0.5 to 4 ppm 5% a.i. formulation) to freshwater environments is intended to kill target fish within a few hours to days. The most exhaustive and thorough testing of rotenone effectiveness against a variety of fish species was done by Marking and Bills (1976) using Noxfish, a liquid formulation containing 5% rotenone. Generally, salmonids and perches are considered the most sensitive to rotenone, followed by sunfishes and sensitive minnows, with the bullhead catfishes and more tolerant minnows being the least sensitive (Table 1.3). The toxicity (24-h LC50 values) of rotenone to fish varies within one order of magnitude from 0.8 ppb for Walleye to 33.2 ppb for Black Bullhead. Rotenone is an acute poison with chronic toxicity values resembling (within a factor of 2) acute toxicity values for trout and cladocerans (Table 1.4). There is likely little chance for chronic exposure given rotenone's instability in the environment detailed above. Exposure of aquatic organisms outside the intended treatment area is limited through rigorous application of this manual's SOPs. In flowing water environments, rotenone is deactivated with potassium permanganate to prevent its movement out of the treatment areas.

Table 1.3. Acute toxicity (24-h LC_{50} values as ppb rotenone) of technical rotenone and various liquid emulsifiable rotenone formulations to fish.

Species	24-h LC_{50}	Formulation	Reference
Coho Salmon *Oncorhynchus kisutch*	3.78	Noxfish	Marking and Bills (1976)
Rainbow Trout *O. mykiss*	3.4	Noxfish	Marking and Bills (1976)
	6.5 (4.2–9.8) n = 7 lots	CFT Legumine	McMillin and Finlayson (2008)
	3.72 (3.69–3.75) n = 2 tests	Technical rotenone	Bills and Marking (1986)
Atlantic Salmon *Salmo salar*	1.85	Noxfish	Marking and Bills (1976)
Brook Trout *Salvelinus fontinalis*	2.45	Noxfish	Marking and Bills (1976)
Lake Trout *S. namaycush*	1.3	Noxfish	Marking and Bills (1976)
Northern Pike *Esox lucius*	2.3	Noxfish	Marking and Bills (1976)

Table 1.3. Continued.

Species	24-h LC_{50}	Formulation	Reference
Carp *Cyrpinus carpio*	4.2	Noxfish	Marking and Bills (1976)
Green Sunfish *Lepomis cyanellus*	10.9	Noxfish	Marking and Bills (1976)
Bluegill *L. macrochirus*	7.4	Noxfish	Marking and Bills (1976)
	8.9 (7.8–10.0) *n* = 2 tests	Noxfish	Bills and Marking (1986)
	8.9 (8.8–9.0) *n* = 2 tests	Technical rotenone	Bills and Marking (1986)
Channel Catfish *Ictalurus punctatus*	20.0	Noxfish	Marking and Bills (1986a)
Black Bullhead *Ameiurus melas*	33.2	Noxfish	Marking and Bills (1986a)
Yellow Perch *Perca flavescens*	4.6	Noxfish	Marking and Bills (1986a)
Walleye *Stizostedion vitreum*	0.8	Noxfish	Marking and Bills (1986a)

Table 1.4. Acute and chronic toxicity of technical (and formulated product where noted) rotenone to a variety of animals.

Species	Toxicity Value	Reference
Pheasant *Phasianus colchicus*	Oral LD_{50} = 1680 mg/kg	Hudson et al. (1984)
Duck *Anas platyrhychos*	Oral LD_{50} > 2200 mg/kg	Hudson et al. (1984)
Rat (Female)	Oral LD_{50} = 39.5 mg/kg	Eiseman (1984)
Rattus norvegicus	Oral LD_{50} = 320 mg/kg[a]	Lowe (2006a)
Honey Bee *Apis* sp.	LD_{50} = >60 µg/bee	Stevenson (1978)
Rainbow Trout	96-h LC_{50} = 2.72 ppb	Bills and Marking (1986)
Rainbow Trout	32-d MATC = 1.49 ppb	Bills et al. (1986)
Cladoceran *Daphnia magna*	48-h LC_{50} = 3.7 ppb	Rach et al. (1988)
Cladoceran *D. magna*	21-d MATC = 1.77 ppb	Rach et al. (1988)
Caddisfly *Hydropsyche* sp.	8-h LC_{50} = 174 ppb[a]	Finlayson et al. (2009)
Stonefly *Operla barbara*	8-h LC_{50} = 102 ppb[a]	Finlayson et al. (2009)
Ostracod *Cypridopsis* sp.	24-h LC_{50} = 24 ppb[b]	Chandler and Marking (1982)
Tadpole *Rana sphenocephala*	24-h LC_{50} = 29 ppb[b]	Chandler and Marking (1982)

[a] Toxicity of rotenone in CFT Legumine formulation
[b] Toxicity of rotenone in Noxfish formulation

Since rotenone is applied directly to water, EPA considers the risk of terrestrial animal acute mortality to be low since there are not likely to be rotenone residues on terrestrial animal forage items. There are insufficient quantities of rotenone to represent a risk of acute effects in terrestrial animals that have consumed fish killed by rotenone or rotenone treated water (EPA 2007). The toxicity of rotenone to most terrestrial organisms is in the ppm range while that to most aquatic organisms is in the ppb range (Table 1.4). The toxicity of technical (pure) rotenone, required in standard toxicity tests for determining impacts to public health, may be at least twice as toxic to animals as rotenone in commercial piscicide formulations (EPA 2007). Hence, test results using technical rotenone may be conservative (effect is more severe) in predicting impacts. This difference in toxicity between mammals and fish coupled with its lack of environmental persistence, make rotenone an ideal piscicide. Since fish rapidly decompose and sink to the bottom of treated water, the likelihood of chronic exposure through the diet of terrestrial animals is also considered to be low (EPA 2007).

Rotenone is practically non-toxic to honeybees on an acute contact exposure basis, is slightly toxic to birds on an acute oral and subacute dietary exposure basis, and is highly to moderately toxic to rats on an acute oral exposure basis, depending on purity (Table 1.4). Rotenone is also acutely toxic to immature insects and frog tadpoles. Rotenone is isolated from plants and was routinely used in the past as an insecticide on plants; thus, adverse effects on plants are not expected.

1.6 Public Health and Concerns

Exposure—Occupational and non-occupational exposure to rotenone from liquid formulations is limited to short-term and intermediate-term exposure from two pathways, oral and dermal; exposure to rotenone from powders includes the inhalation pathway. Chronic exposure is unlikely but possible from drinking water (oral). Adverse effects are unlikely given the rapid degradation of rotenone. Chronic exposure through food is not expected because of rotenone's rapid degradation and low propensity to bioaccumulate.

Acute Toxicity—The acute toxicity profile required by FIFRA for pure rotenone is complete (Table 1.4). Technical rotenone is acutely toxic via the oral and inhalation routes of exposure (EPA Highly Toxic Category I), with female rats more sensitive than male rats. However, rotenone in formulations appears less toxic than technical rotenone. Hence, assessments based on tests with technical rotenone are likely conservative in estimating actual risks from rotenone in formulations. Rotenone is neither corrosive nor irritating to the skin or eye and is not a dermal sensitizer. The dermal toxicity is >5,000 mg/kg. Rotenone does not easily penetrate human skin; <0.37% of rotenone applied in CFT Legumine is absorbed through human skin (Swan 2007).

Chronic Toxicity—The chronic toxicity profile by FIFRA for rotenone is relatively complete (Table 1.5). Oral dosing studies for rotenone include an oral 90-day subchronic with dogs (Ellis et al. 1980), oral developmental toxicity with rats and mice (MacKenzie 1981; 1982), reproduction with rats (MacKenzie 1983), carcinogenicity with mice, rats, and hamsters (Freudenthal 1981; Greenman et al. 1993), and combined chronic/cancer with rats (Tisdale 1985). Rotenone was negative in several *in vitro* mutagenicity assays (National Toxicology Program 1984). There are two chronic feeding studies for rats and mice (National Toxicology Program 1986). The primary route of excretion of rotenone in rats is in the feces with polar metabolites identified. Rotenone undergoes enterohepatic circulation with the tissue accumulation being low, typically less than 1% of administered doses. The most common toxic effect in animal studies from intermediate or long-term oral exposure was decreased body weight or body weight gain (EPA 2007). Rats are generally more sensitive than mice, and in both species, females are more sensitive than males to the effects on body weight. No evidence of carcinogenicity was seen in animal studies. No treatment-related structural external, visceral, or skeletal abnormalities were found in fetuses from treated females.

Table 1.5. Acute, subchronic, chronic, developmental, and reproductive toxicity profile on technical rotenone and CFT Legumine (Lowe 2006a, 2006b). Modified from EPA 2007.

Species	Toxicity Value	Reference
Acute oral (rat)	LD_{50} = 102 (M) 39.5 (F) mg/kg LD_{50} = 320 mg/kg (F)	Eiseman 1984 Lowe 2006a
Acute dermal (rabbit)	LD_{50} = >5,000 mg/kg	Gabriel 1996
Acute inhalation (rat)	LD_{50} = 0.024 (M) 0.019 (F) mg/L LD_{50} > 0.062 (M&F)	Hobert 1995 Lowe 2006b
Acute dermal irritation (rabbit)	PIS 0.08 at 1 hr	Moore 1995a
Acute eye irritation (rabbit)	PIS 3.3 at 1 hr	Moore 1995b
Skin sensitization	Not a dermal sensitizer	Kuhn 1995
90-day oral (dog)	NOAEL = 0.4 mg/kg/day LOAEL = 2 mg/kg/day	Ellis et al. 1980
Developmental (rat)	Mat NOAEL = not determined Mat LOAEL = 0.75 mg/kg/day Develop NOAEL = 3 mg/kg/day Develop LOAEL = 6 mg/kg/day	MacKenzie 1982
Developmental (mouse)	Mat NOAEL = 15 mg/kg/day Mat LOAEL = 24 mg/kg/day Develop NOAEL = 15 mg/kg/day Develop LOAEL = 24 mg/kg/day	MacKenzie 1981
Reproduction (rat)	Parental NOAEL = 0.5/0.6 mg/kg/day Parental LOAEL = 2.4/3.0 mg/kg/day Repro NOAEL = 2.4/3.0 mg/kg/day Repro LOAEL = 4.8/6.2 mg/kg/day Offspring NOAEL = 0.5/0.6 mg/kg/day Offspring LOAEL = 2.4/3.0 mg/kg/day	MacKenzie 1983
Chronic/Oncogenicity (rat)	NOAEL = 0.375 mg/kg/day LOAEL = 1.88 mg/kg/day No evidence of carcinogenicity	Tisdale 1985
Chronic/Carcinogenicity (mouse)	NOAEL = <111/124 mg/kg/day LOAEL = 111/124 mg/kg/day No evidence of carcinogenicity	National Toxicology Program 1986
Carcinogenicity (hamster)	NOAEL = 42 mg/kg/day LOAEL = 83 mg/kg/day	Freudenthal 1981

Table 1.5. Continued.

Species	Toxicity Value	Reference
Gene mutation (*S. typhimurium*)	No evidence	Haworth 1978
Gene mutation (mouse lymphoma)	Evidence of concentrated-related response of induced mutant colonies w/o metabolic activation	National Toxicology Program 1984
Micronucleus (mouse)	Negative at doses to 80 mg/kg/day	Biotech 1981

Carcinogenicity—Rotenone was classified as Group E, no evidence of carcinogenicity in humans by the Cancer Assessment Review Committee of EPA on September 29, 1988. No evidence for carcinogenicity was seen in hamsters, mice, or rats from available carcinogenicity studies. Administration of rotenone at doses up to 75 ppm (3.75 mg/kg/day) to rats for two years did not result in an increase in overall tumor incidence or increase in incidence of any specific type of tumor (Tisdale 1985).

Parkinson's Disease (PD)—A definitive target organ for rotenone toxicity has not been identified although it is known that rotenone uncouples oxidative phosphorylation by blocking electron transport at complex I within the mitochondria. Published literature within the past 15 years indicate rotenone inhibits the activity of the mitochondrial electron transfer chain but can also reproduce some features of PD (Betarbet et al. 2000), including selective nigrostriatal dopaminergic degeneration and microglial activation (Sherer et al. 2003). These studies used intravenous and subcutaneous routes which are not relevant to humans. Although rotenone is toxic to the nervous system of insects, fish, and birds, commercial products have presented little hazard to humans over many decades (Reigart and Roberts 1999). In his chapter on inhibitors of oxidative phosphorylation (including rotenone), Hollingworth (2001) does not consider rotenone a cause of PD. More recently, Rojo et al. (2007) found that mice and rats subjected to chronic inhalation of rotenone were asymptomatic for PD, and the amount of rotenone that might reach the brain through the nasal route appeared insufficient to produce a significant neuron loss. A review of the published data since the initial study by Betarbet et al. (2000) suggests that their rotenone-treated rats' model is based on atypical Parkinsonism rather than idiopathic PD, and that such studies are not applicable to the application of piscicidal rotenone (Höglinger et al. 2006).

The Agricultural Health Study (Kamel et al. 2006; Tanner et al. 2011) evaluated the previous use of pesticides by farmers and their incidence of PD. Tanner et al. (2011) concluded that rotenone and paraquat use were associated with increased risk of PD. However, the study participants were exposed to many different pesticides, not just rotenone and paraquat, and pesticide exposures were not actually measured; rather, pesticide exposures were based solely on self-reporting methods and recollection. Raffaele et al. (2011) discussed the problems associated with using epidemiological data in environmental risk assessments, specifically citing as examples studies on pesticide exposure contributing to the increased risk of PD. They found inconsistent findings between studies, generic categorization of pesticide exposure, and the use of dichotomous exposure categories (e.g., "ever" versus "never"). They also noted the difficulty in using epidemiological studies to evaluate a disease such as Parkinson's where multiple causal factors (genetic susceptibility, age, and environmental exposures) are present. Collectively, the toxicology and epidemiological studies present no clear evidence that rotenone is causally linked to PD. Even if there were clear evidence, it would have little impact on the current and proposed use of rotenone in fish management. This is because the toxicology studies demonstrating PD-like effects were conducted using routes of exposure (e.g., intraperitoneal or intravenous injection or oral dosing with solvents) and

exposure regimes (e.g., weeks to months) not germane to potential human exposure associated with fishery uses.

For the applicator, the use of required PPE will significantly reduce, if not eliminate, exposure. For the general public, restricted access to the treatment area until rotenone subsides to safe levels and the use of potassium permanganate to deactivate water leaving the treatment area will greatly minimize exposure. Although everyone is at some risk of developing PD, the risk of developing PD-like symptoms as a result of rotenone exposure from use in fish management is negligible because with recommended care, rotenone exposure has been effectively eliminated.

1.7 Interaction with the Public

The AFS FMCC *recommends* close interaction between the public and the natural resource agency using rotenone to ensure that public concerns are adequately addressed prior to initiating the project. Public involvement should begin at the most elemental stages of a project, typically at the development of a species-specific or water body-specific fish management plan. Rotenone is a tool used in fish management, and it is difficult to gain support for a project when there is no support for the management plan that requires rotenone treatments. Public acceptance can be gained through a variety of processes, including building consensus, accommodating concerns, or by earning their consent. A successful public engagement process includes demonstrating to the public that (1) there is a problem, (2) the natural resources agency is the one to solve it by presenting success stories of previous treatments, (3) the agency's approach is reasonable, (4) alternatives have been sufficiently vetted and considered, and (5) the agency is listening and responding to the public comments. The process may require outside facilitation.

In the past several decades, rotenone use has been temporarily prohibited or become more restrictive in several states and provinces (California, Idaho, Montana, Michigan, Oregon, Arizona, and New York). These actions were initiated by different entities including Center for Biological Diversity, Pacific Environmental Law Center, Californians for Alternatives to Toxic Substances, and state agency California Regional Water Quality Control Board, Lahontan Region. Cancellation of rotenone projects have placed federally-listed species at continued risk of extinction (Finlayson et al. 2005). Frequently, the lack of public acceptance for using chemicals in water and killing fish is at the root of the challenges mounted by opposition groups that become organized, secure funding, and mount legal challenges. Future uses of rotenone, even for small projects, are now threatened in several states and provinces. Often, small projects generate the greatest controversy. The controversy in many cases originates from the lack of public understanding on management decisions, purpose(s), and environmental tradeoffs associated with the project. Information on these elements will usually increase public understanding and yield a greater acceptance for the use of chemicals and the killing of fish.

In a 1998 survey of natural resources agencies in the United States and Canada, many agencies reported on issues associated with the use of rotenone (McClay 2000; Finlayson et al. 2000). Agencies overwhelmingly identified public acceptance and understanding, environmental concerns, and the "usability" of the product as the most important issues confronting them. Specifically, agencies requested information and guidance on the following broad categories (in order of frequency mentioned): (1) collection and disposal of dead fish; (2) impact of rotenone and other ingredients on public health; (3) impact of rotenone and the other ingredients on surface and groundwater quality; (4) adequate public notification and involvement; (5) impact of rotenone on fish; (6) impact of rotenone on wildlife; (7) impact of rotenone on invertebrates; (8) rotenone residues in fish; (9) liability and property damage; and (10) impact of rotenone and other ingredients on air quality.

A Public Information Program is crucial to informing the public on the benefits and impacts of rotenone use; however, dispelling fears may not always be possible. As more demands are placed on the continent's bodies of water and the public becomes more environmentally aware, there will be a need to respond with information on how rotenone is being used in a manner to minimize environmental impacts. The revised labels and procedures in this *Rotenone SOP Manual* reflect mitigation measures that

lower risks identified in the assessment to human health, recreational, occupational, and ecological risks (EPA 2007).

The two most important concepts that natural resources agencies should incorporate into rotenone projects are (1) public acceptance can come from public understanding, and (2) public input minimizes controversy. Involving the public early in the decision-making process is crucial to public understanding and acceptance. Informing the public of a project likely will require a public meeting where a brief narrative on the project is presented. The narrative should focus on alternatives to correcting the fish management problem, nontechnical information on rotenone, explanation of project and schedule, and anticipated benefits of the project. The public will likely be interested in the project if they attend the meeting, and the agency should be a good listener and ask for their comments. Agencies should strive to accurately and clearly communicate project objectives, environmental trade-offs and the consequences of doing nothing to the public. Public support for renovating a fish community may be generated when managers can demonstrate that the current community is the result of human-induced perturbations and that the preferred alternative is complete renovation. The public often does not understand that some short-term losses may be offset by long-term benefits such as native fish restoration, improved habitat, or many years of improved angling opportunity. Some agencies have done a great job in documenting their successes and using those to garner support for future projects. These success stories, especially if in written form, should be shared among agencies so others including the public can benefit from relevant successes of others.

1.8 Product Stewardship

Product stewardship is a concept where environmental protection centers on the prudent use of the product and everyone involved in the use of the product is asked to take responsibility for reducing its environmental impact. Actions include treating at effective but not excessive levels, treating when environmental conditions will limit non-target impacts, carefully considering public input, improving the public's understanding of why rotenone projects are needed, and deactivating rotenone containing water leaving the treatment area. This concept is a natural fit for the piscicide rotenone since its use can be controversial because of environmental and public health concerns. Not practicing stewardship often results in time-consuming public relations and environmental regulatory problems. AFS maintains a Rotenone Stewardship Program website (www.rotenone.fisheries.org).

1.9 Rotenone SOP Manual Structure, Updates and Terminology

This manual is divided into four chapters: (1) Introduction, (2) Project Planning Procedures, (3) Biological Sampling and Monitoring, and (4) Standard Operating Procedures. The first three chapters give the fishery manager background information on rotenone's (a) attributes and historical use, (b) environmental fate and behavior, (c) safety to the environment, non-target organisms, and humans, (d) reregistration history, (e) project planning procedures, and commonly used monitoring methodology. The techniques for using rotenone are outlined in 16 SOPs located in Chapter 4. SOPs may be revised or new SOPs may be added and approved by the EPA in the future. Applicators should check the AFS website www.rotenone.fisheries.org frequently for changes. The reference to the revision is listed as SOP #.* (# is SOP number and * is revision number). Readers can submit comments to the AFS webpage.

The words "must," "should," "may," "can," and "might" have very specific meanings in this manual:

"Must" is used to express an absolute (mandatory) requirement, that is, to state that the guidelines are designed to satisfy the specified condition. "Must" is only used in conjunction with factors that directly relate to the legality or acceptability of specific recommendations (i.e., a requirement on the label of a pesticide product).

"Should" is used to state that the specified condition is recommended (advisory) and ought to be met, if possible. Terms such as "is desirable," "is often desirable," and "might be desirable" are used in connection with less important factors.

"May" is used to mean "is (are) allowed to."
"Can" is used to mean "is (are) able to."

1.10 References

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2 Rotenone Project Planning Procedures

The size and complexity of the rotenone project will dictate the amount of planning required. A rotenone project usually will have five stages: (1) preliminary planning, where the project concept and alternatives are developed, public input is invited, and acceptance is encouraged; (2) public and agency review where the scope of the project is refined based on public input, regulatory compliance and environmental assessment; (3) final planning and project implementation, involving development of project-specific work plans to accomplish the goals of the project; (4) performing the treatment; and (5) completion of the project's goals and critique of the project into a final report (Figure 2.1).

A small treatment performed on private land or a government-owned hatchery may require little planning before implementation, while a large project involving a public water supply may require two or more years of planning, discussions, and conflict resolution. The goals of the project should be consistent with and supported by the current Fish Management Plan when applicable.

2.1 Preliminary Planning of Proposed Project

Preliminary planning is critical to the success of fish reclamation and sampling projects using rotenone. The project plan should be based on facts and tactics that firmly stand throughout the whole process. Key ingredients in preliminary planning usually include: (1) public involvement; (2) FMP; (3) statement of need; (4) determination of applicable laws and regulations; and (5) internal agency review and approval. Once these elements have been completed, an outline of a preliminary treatment plan is usually beneficial to define the scope of the rotenone project for future planning.

2.1.1 Public Involvement

The public needs to be involved in the rotenone project beginning with the development of the FMP at the preliminary planning stage. The public should continue to be involved as the project is developed and executed. At the completion of preliminary planning, a Public Involvement Plan should be in place to ensure a formal process for public input and notification should address the following:

- Identify each milestone for public involvement including a schedule for initial public notice, public meetings, written comments, final decisions, and notifications (in short, a road map for the project)
- Identify key interest individuals, groups and agencies
- Enlist key support groups and allies and assign contact persons
- Notify news media and assign contact persons
- Anticipate responses from individuals, groups and agencies and focus efforts on those likely to oppose
- Assess methods to inform and obtain public comment to ensure that the public is informed and their input is received and assessed

To be successful, a majority of the public should acknowledge that the project is a reasonable means of correcting the conflict with the goals of the FMP.

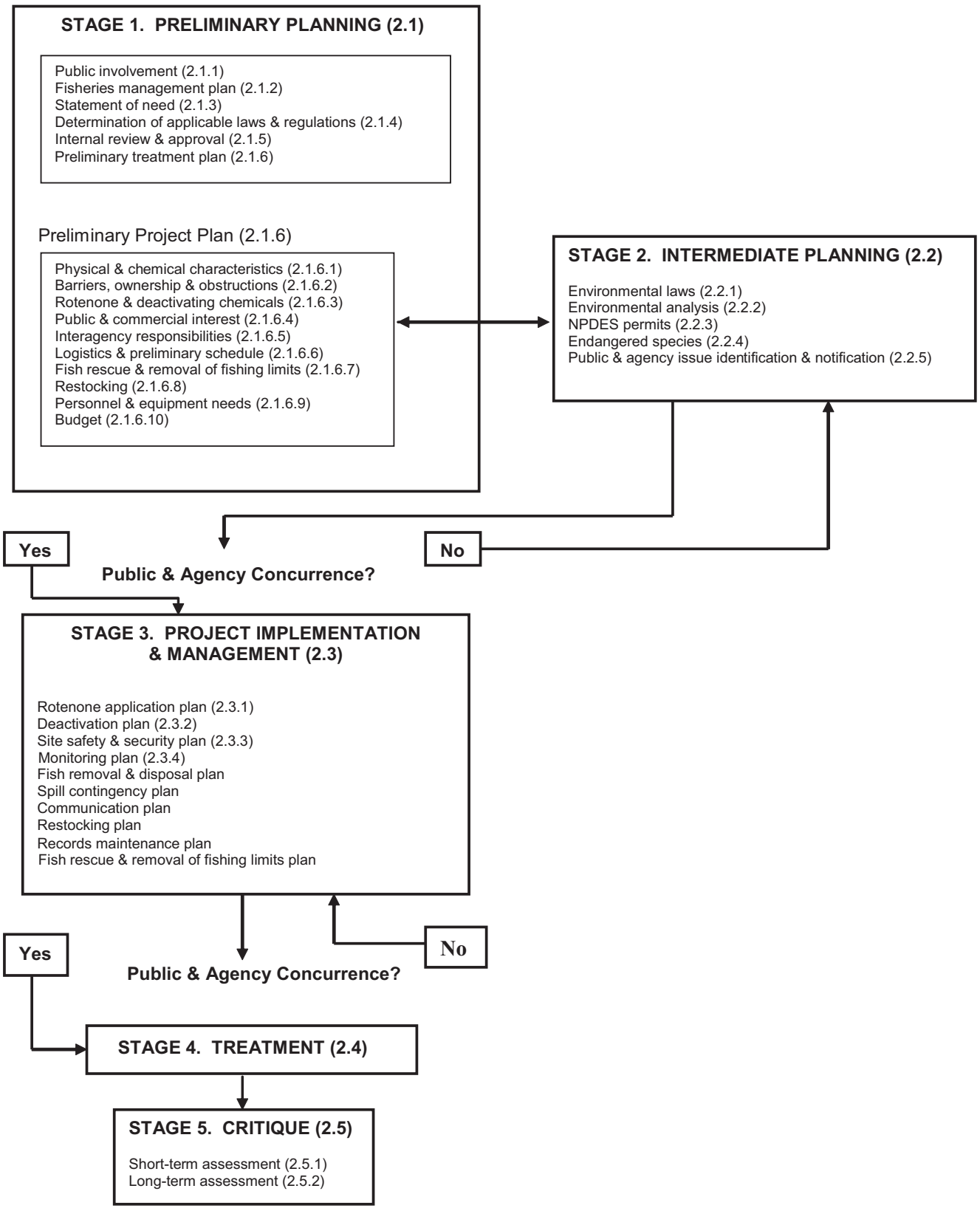


FIGURE 2.1. Five (three planning) stages of a rotenone project.

Informing the public of the project usually involves a public meeting where the project is presented with an emphasis on the problem, and the agency asks for comments. Individual states may have administrative procedures that must be followed in regard to holding public meetings. The level of attendance at these meetings is usually a good indicator of their interest (support or concern) in the project. A brief narrative is usually prepared for the public that lists alternatives to correcting the problem, nontechnical information on rotenone, an explanation and schedule for the proposed project, and anticipated benefits to the resource and the public.

2.1.1.1 Preventive planning

The lead agency for the project should engage the public early in the process to avoid problems later that may require professional conflict management in the form of legal and public relations assistance. Resources are more efficiently spent on preventing rather than managing conflicts later on. Public meetings and early disclosure of information is considered part of preventive planning and is an easy and inexpensive means of avoiding later expensive conflict management.

The lead agency should train their staff in conflict management including working early and often with stakeholders. Disengaging the stakeholders will likely lead to mistrust and disrespect. Getting stakeholders to unanimously agree on a project may be impossible, but engaging them early and often will normally preclude them from attempting to politically or legally veto the project. If the project is viewed as legitimate, credible and fair, stakeholders rarely veto the project.

Developing an early warning system that monitors stakeholder concerns in newspapers and meetings and whether stakeholders are acting on their concerns is part of preventive planning. As mentioned above, the lead agency should take the initiative to the stakeholders on the agency's terms in the form of a public meeting. Do this in a manner that demonstrates a legitimate concern that needs action, your proposed action is a credible solution, and the decision is being derived in a fair process.

2.1.1.2 Contingency planning

The lead agency should identify and address windows of vulnerability associated with the project. Often these will emerge from the stakeholder's interests and concerns. If there have been previous problems with chemical treatments, there should be solutions that address the underlying concerns. Further, the agency should conduct "what if" analyses to identify vulnerabilities associated with the project and how might the agency respond (options) should these occur.

Previous rotenone projects have had problems that were capable of becoming conflicts/crises. These included:

- Deactivation of rotenone with $KMnO_4$ failed and fish were killed outside the project area
- "Pesticide" odors and reported illnesses occurred
- Water quality concerns where the formulation chemicals persisted longer than expected
- Dead or sick livestock were found in and adjacent to the project area
- The project failed to accomplish the stated project objectives
- There was excessive public opposition to the project and/or its objectives

2.1.1.3 Conflict management

Despite sufficient prevention and contingency planning, unplanned actions becoming problems may emerge during the project. These can become conflicts among parties and grow more difficult to control and resolve if left unchecked and unmanaged. For this reason, a crisis management plan should be developed before the treatment. This action plan prepares the agency for any negative development that may jeopardize the rotenone application or its favorable outcome. Before treatment, a crisis team should be identified that will act as an early alert group to develop the situation responses to problematic activities including those listed above. Some elements to consider in a crisis management plan are:

- The crisis team should include:
  - Early alert members (i.e., persons who can handle the crisis and devote exclusive time to the crisis)
  - Primary response members (i.e., technical experts in various disciplines)
  - Secondary response members (i.e., high-level persons in the agency, elected officials, and law enforcement)
  - Support groups

- The situation response comprises the following steps:
  - Defining the problem and scope
  - Identifying targets and issues
  - Selecting appropriate crisis team
  - Gathering facts
  - Identifying a spokesperson

- Support groups normally consist of members from:
  - Research groups
  - Sports clubs, associations, and organizations
  - Regulatory governmental agencies.

- If faced with a crisis, the following will assist with its management:
  - Defining the real problem
  - Gauging public actions and opinions, perhaps by using a newspaper clipping service or Internet
  - Focusing on long-term consequences and corrective actions, do not focus on the details or blame
  - Delegating details to support groups

- Resist combative instincts and keep control, or control of the situation will be lost

- Centralize control of information that is released to the public and keep the message consistent and clear

- Communicate and negotiate at the highest level, following the chain-of-command and brief all involved

- Contain the problem quickly and stop the erosion of public confidence.

2.1.2 Fish Management Plan

In the United States, fish and wildlife resources are held in trust for the public by state and federal management agencies. Responsible stewardship of the fishery resources usually involves the creation of a Fish Management Plan (FMP), which assess the status of a specific water body or populations of specific fish species and determines the appropriate management actions necessary to maintain the desired fishery. Public input should be sought during the development of the FMP, which will in turn increase the likelihood that they will support the finished plan. This will be especially critical when rotenone is identified as a tool to achieve management objectives.

A FMP can take many forms depending on the need. Most common are plans for a game or endangered fish species, a waterbody, or an invasive species. Properly written, a FMP ensures that written goals and objectives for a specified time period are clearly defined and implemented. The type of management desired will determine which type of FMP is used. An FMP for an invasive species will more typically detail options for eradication or suppression.

A species-specific FMP minimally contains the following items:

- Goals and objectives
- Historic habitat range of managed species
- Description of environmental and human problems
- Identification and prioritization of suitable habitat locations, including threats to each habitat type
- Plan description
- Timeline of management measures

A FMP for a specific water body is similar to the species-specific plan except that this plan includes a description of the biotic diversity of the water body instead of a habitat range for the species. The water body specific FMP should contain the following:

- General geographical setting of the area
- Description of existing land management surrounding the water body
- Water quality and development surrounding the water body (e.g., forest, residential, industrial)
- Recreational facilities and activities
- Ownership
- Hydrology
- Aquatic animal assemblages and habitat types
- Threatened and endangered species
- Fishery description
- Current fish management and proposed management program (objectives, direction, recommendations)

A FMP for an invasive species may resemble a species-specific plan, especially if the invasive species is already established. If not established within the jurisdiction of the management agency, the FMP will more often be in the form of a “rapid-response plan” which details how the agency will respond when a report of the species is received. Iterative steps in this response are:

- Assessing the validity of the report and if true, evaluating the abundance, population structure, and reproductive potential of the species
- Developing proposed management actions, often including a decision-making process on whether or not to use rotenone
- Public input process describing how the public will be engaged
- Implementation of the chosen action
- Evaluating the success of the management action

2.1.3 Statement of Need

A statement of need for a rotenone project should be supported by a logical progression from a FMP or other ecosystem plan. The need for a project should be clearly supported by factual evidence. For example, the presence of undesirable fish as defined by the fisheries manager may suggest rotenone treatment. The objective of the project is to correct existing fishery conditions that conflict with the goals of the FMP. Project objectives might include reversing unacceptable declines in population size or growth rate of a desirable fish species, eliminating undesirable species, minimizing outbreaks of contagious disease, reintroducing a native species into its historical range, or changing the desired species composition in response to public demand. The justification should also include consideration of prevailing on-site regulations and management plans, the current and potential demand for fishing within the water body, the need to protect nearby waters from undesirable species, or the uniqueness of a remote, native fishery. Projects that emphasize single species management should address issues of ecosystem diversity. Knowledge of the presence of parks or other public facilities (or possible future developments), and the proximity of population centers is useful for this process. The justification should also explain why other options would not accomplish the desired results. If an environmental analysis is planned (see Section 2.2.2), the draft document should evaluate all realistic options or alternatives. Small projects that do not require an environmental assessment should include a clear justification for the decision to use rotenone.

Before proposing a project, a biological survey of fish community composition is necessary. At a minimum, sample a variety of species and age-groups to determine the presence of the most rotenone-resistant species subject to removal. The justification may contain measures of angler success and use such as creel survey information and fish stocking information. Written or oral comments solicited from the angling public can provide information about general satisfaction with a fishery. The justification should include a description of the fish community, desired fish management objectives, life history of the target fish species, and a comparison of the available alternative control measures. The project might also have population estimation and enumeration as an objective. The appropriate uses of rotenone and alternative control measures are discussed in Section 1.2.

2.1.4 Determination of Applicable Laws and Regulations

State the legal authorization (federal, state, or provincial) for fish and wildlife agency management of aquatic resources. Documentation of this authority may prove instrumental in countering legal challenges to the project and in negotiations with other parties. These mandates usually address the conservation, maintenance, and utilization of natural resources to ensure the continued existence of all species and the maintenance of a sufficient resource to support reasonable recreational fisheries. The natural resources agency may have specific powers to take any species which is unduly preying upon a desirable species of bird, mammal, or fish, an introduced species, or harboring a highly contagious disease.

Determine those regulatory agencies that have overlapping jurisdictions for regulating a treatment. Agencies that regulate the following areas may require notifications, applications, approvals, and permits:

- Agriculture/pesticide regulation
- Water use
- Environmental protection
- Water quality
- Public health
- Land use including designated wilderness
- Threatened or endangered species

Determine the applicable regulations and restrictions, and obtain clearances in sufficient time before the treatment. Outside agencies may need monitoring plans and other requirements before treatment, so allow

sufficient time for compliance. Resolve conflicts over regulatory and jurisdictional issues before treatment. Agreements that delineate interagency authorities, responsibilities, procedures, and timelines have been instrumental in resolving conflicts among agencies with overlapping responsibilities.

2.1.5 Internal Review and Approval

The project should receive internal review and approval using the agency's chain-of-command structure prior to receiving public input. It may be beneficial to use a predetermined format for assessing proposals that provide for written information on the following:

- Ownership and use of the water body
- Interested parties likely affected by the action
- Environmental compliance issues
- Water uses affected by project
- Target species and conflicts with FMP
- Supporting and regulatory agencies affected
- Likely supporting and opposing groups and individuals
- Physical and chemical characteristics of the waterbody
- Chance of success and number of treatments/years required for success
- Threat of target species to surrounding waters
- Chance for eradication from waterbody and larger areas
- Downstream areas affected by project
- Sensitive, endemic, and listed species impacted by project

2.1.6 Preliminary Treatment Plan

The preliminary treatment plan is the first draft of the proposed application from beginning to end. It needs to be completed, reviewed, and tentatively approved internally before moving forward. This plan will likely be refined during subsequent project phases, but it serves as the basis for the operational plans in the Project Implementation and Management (Section 2.3). The preliminary plan should contain and address the following elements to gain an accurate assessment of necessary resources.

2.1.6.1 Physical and non-biological characteristics of the water body

If necessary, there should be an initial survey of the area. The survey's results are used to prepare a general location and morphological map of the system to be treated that describes the following important environmental attributes:

- Distribution of target and non-target species
- Lake depth, surface area, volume, bathymetry, description of seasonal thermocline, inlets, outlets, and residence time
- Stream discharge, length, width, gradient, pool-to-riffle ratio, and travel time through the treatment area and all known waters (i.e., seeps, springs, beaver ponds, wetlands, tributaries) capable of supporting fish
- Amount of open canopy on streams and aquatic vegetation in lakes
- The water temperature, pH, dissolved oxygen, turbidity, alkalinity, and conductivity at anticipated time of treatment

2.1.6.2 Barriers, ownership, and obstructions

Indicate the location and describe the barriers and obstructions to fish movement and water circulation, including aquatic macrophytes, swampy areas, and beaver dams that may require special handling. Indicate and describe human ownership of surrounding land and any legal restrictions associated with that land that might compromise treatment activities.

2.1.6.3 Rotenone and deactivating chemical

Describe the type of formulation, concentrations, and amounts of rotenone likely to be used. The rotenone concentration will depend on a bioassay with the target species in site water under conditions expected during treatment (see SOP 5.1). For lakes, the total amount of rotenone needed will depend on the depth, volume, water clarity, organic content, flushing rate, pH, and water temperature at the time of the proposed treatment. For streams, the total amount of rotenone needed will depend largely on the spacing of drip stations in the treatment area. Typically, a lake or stream is divided into treatment zones, each with specific requirements. Assess the environmental advantages and disadvantages of natural degradation in a lake environment and the use of deactivating agent potassium permanganate for a discharge leaving the treatment area. If chemically-induced deactivation is required, the amount needed will depend on the rotenone treatment rate, amount of water requiring deactivation, and the background permanganate demand of the water (see SOP 7.1). For all treatments, distinguish between the treatment area and project area with the latter including the deactivation zone (see SOP 6.1).

2.1.6.4 Public and commercial interests

Identify and contact public and commercial groups that use the water body, especially if it is a public or industrial water supply. It might be advantageous to involve representatives from these groups. Document ownership of the water licenses held, particularly for inlet and outlet streams.

2.1.6.5 Interagency responsibilities

Contact all government agencies at the local (counties, cities, and reclamation and conservation districts), state, provincial, or federal level that might have plans, permits, authorities, or responsibilities affected by the treatment. These include health, agriculture, parks, environment, water supply and quality, air resources or quality, and land use agencies. It may be desirable to assign an agency contact person for each of these outside agencies.

2.1.6.6 Logistics and preliminary schedule

Summarize the methods of application and deactivation, number of staff needed, timing, required permits and approvals, and biological and chemical monitoring required, and schedule each major milestone. Develop an outline and schedule for all actions required in the Public and Agency Review (see Section 2.2) and Project Implementation and Management (see Section 2.3) sections by selecting a proposed treatment date and working backward with reasonable completion dates for the milestones (see Figure 2.1). Allow for periodic assessments to amend the schedule.

2.1.6.7 Fish rescue and removal of fishing limits

The prospect of wasting fish in a treatment may prompt public concern. Consider the viability of a pretreatment salvage operation to allow the public to remove fish for consumption. Liberalization of fishing regulations will often effectively address these concerns and improve public support. Ensure enough lead-

time to implement regulatory changes. An alternative may be to rescue the desirable fish from the proposed treatment area for transplanting into another water body or for holding at a facility to reintroduce once the treated water body can again support fish. These rescue alternatives are usually expensive but can be good public relations tools, especially if the public gets involved.

2.1.6.8 Restocking

Most, but not all rotenone projects will be followed with an effort to restock the treated water body. Develop a restocking plan based on the proposed treatment date, management objectives, and expected completion date. The restocking effort should be consistent with the current FMP. Public resistance to a treatment may be due to an unwillingness to accept lost fishing opportunities or the loss of quality-sized fish. In such cases, there may be a demand for immediate stocking of large catchable fish. If such a demand can be anticipated in advance, it gives managers time to make arrangements with hatcheries to meet these needs.

2.1.6.9 Personnel and equipment needs

Determine personnel and equipment needs (purchased and rented) for pretreatment, treatment, and post treatment. In addition to the application and deactivation operations, this estimate should include working with the public, environmental analysis, fish rescue, monitoring, dead fish removal and disposal if needed, and fish restocking.

2.1.6.10 Budget

Determine all personnel, rotenone, potassium permanganate, legal, material, and equipment (including special items) costs for the pretreatment, treatment, and post-treatment activities of the project.

2.2 Public and Agency Review

This intermediate planning stage refines the preliminary project plan and clears obstacles for the treatment before the final planning stage of developing site-specific plans to implement the treatment in Project Implementation and Management (see Section 2.3).

2.2.1 Environmental Laws

Several federal laws will likely affect the project include Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, see Section 2.2.3), National Environmental Policy Act (NEPA, see Section 2.2.2), Clean Water Act (CWA, see Section 2.2.3), Endangered Species Act (ESA, see Section 2.2.4), and Occupational Safety and Health Act (OSHA, see Section 2.2.5). Many states and provinces have statutes with similar restrictions that may also affect the project.

2.2.2 Environmental Analysis (EA)

An EA, not to be confused with a National Environmental Protection Act (NEPA) Environmental Assessment, typically focuses on environmental impacts of the project, methods of reducing environmental damage through alternatives or mitigation, and disclosure of rationale for the project. Scheduling an EA depends on the complexity of the project and the issues involved, but the document should be completed and approved before moving to Project Implementation and Management (see Section 2.3). Ideally, the collection of information for the EA should begin sometime during the latter stages of Preliminary Planning of the Proposed Project (see Section 2.1) to assist in defining the project scope. An EA may require one or two year's lead time, depending on the requirements of the responsible agency, project size and complexity,

and project issues. For projects proposed on federal lands, ensure that advance coordination with federal management agencies and necessary approvals and documentation are completed prior to commitment of resources.

Environmental quality laws codify specific policies of federal, state, and provincial governments. These policies typically provide for maintaining a quality environment, identifying critical thresholds for personal health and safety, encouraging systematic and concerted efforts for management of natural resources and waste disposal, encouraging the enjoyment of esthetic values of natural resources, preventing the elimination of fish and wildlife species, and requiring government agencies to consider alternatives with lower environmental impacts.

In the United States, the NEPA (1970) sets forth a systematic approach for evaluation of the environmental impacts (biological, physical, and social-economic) of federal actions, those permitted by a federal agency or those using federal funds. Many states and provinces have similar review processes. For proposals subject to NEPA, an agency must evaluate and consider all reasonable alternatives including No Action (status quo) and must suggest appropriate mitigation measures, but is not bound to them.

Whether subject to NEPA or state or provincial environmental quality review, the normal procedure is to conduct a preliminary analysis (i.e. scoping) to determine whether the proposed treatment is categorically excluded from the need for further consideration, whether to prepare an environmental assessment (under NEPA) to ascertain if the project will have no significant adverse impact on the environment or if the impact can be mitigated. For example on USDA Forest Service (FS) managed lands, scoping can be limited to internal FS review and issuance of a categorical exclusion if the responsible agency coordinates with the FS, the action is consistent with protection of FS lands, and the action is in compliance with all regulations (i.e., FIFRA and Clean Water Act). However, an environmental impact statement (under NEPA) is prepared if a significant unmitigated adverse impact on the environment or an environmental change is expected.

Several states including California, Washington, and Michigan have prepared programmatic environmental studies of rotenone use in fisheries management (MDNR 1990; WDFW 1992; CDFG 1994) allowing specific rotenone projects to be supported by the programmatic document. The programmatic documents serve to minimize redundancy on issues from project to project, act as a reference for the hazards of rotenone use, treatment methods, and safety procedures, and generally depict the expected impacts of rotenone use.

The draft EA should be released for public review if required before agency approval is finalized. The agency should notify the public of the draft document by placing a notice in a local newspaper of general circulation in the project locale and by sending copies to interested groups. Alternatively, a notice of the draft document can be published on the state or provincial agency website. The notice should indicate the time period for public comment, a brief description and location of the project, and how to obtain a copy of the draft document. Consider all written comments before final approval of the EA.

2.2.3 National Pollution Discharge Elimination System (NPDES) Permits

The objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands. The EPA through CWA regulates waste discharges through the issuing of NPDES Permits and sets standards for maintaining water quality. A rotenone application that involves a discharge from the treatment area will likely require coverage under an NPDES Permit called Pesticide General Permit, which limits rotenone residues and toxicity, requires Integrated Pest Management, and a monitoring program. Most states have the authority to write and issue NPDES Permits.

2.2.4 Endangered Species

Depending on the location, the use of rotenone products may implicate ESA obligations for federal agencies and other persons using these products. Agencies and others should contact their local National Oceanic

and Atmospheric Administration (NOAA) office and FWS Ecological Services office at www.fws.gov/offices for assistance. Contact should be made approximately 6 months in advance of the planned rotenone application date since significant review may be required.

The ESA (1973) provides a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved. Among other protections, ESA accomplishes this purpose through two mandates: Section 7 consultation and Section 9 take prohibitions. Section 7 is germane to federal agencies; in this case it applies to any federal agency applying rotenone and any federal agency providing funding to a non-federal agency for the application of rotenone. Section 9 is applicable to all persons. Section 6 allows for management agreements with states to manage threatened and endangered species.

Section 7(a)(2) of the ESA requires all federal agencies to ensure their actions do not jeopardize existence of listed species or adversely modify or destroy their critical habitat. Actions include all activities and programs of any kind authorized, funded, or carried out, in whole or in part, by a federal agency. To ensure this Section 7 mandate is fulfilled, federal agencies must follow procedures prescribed in regulation. In brief, if no listed species are present or will not be affected in any manner, no further consultation is needed. If listed species are present and "may be affected," the action agency must assess the impacts upon such species. If their biological assessment (BA) indicates listed species "may be affected but are not likely to be adversely affected" consultation may be concluded informally with written concurrence from the FWS or NOAA, the administrators of the ESA. If the action is "likely to adversely affect" listed species, formal consultation is required. The culmination of formal consultation is a written biological opinion that puts forth "jeopardy" or "no jeopardy" determination. In the former, the biological opinion identifies reasonable and prudent alternatives, which must be taken to avoid jeopardy. In all cases where incidental take is likely to occur, the biological opinion includes an "Incidental Take Statement," which provides exemption for the incidental take of listed species.

Section 9 of the ESA prohibits take of listed species. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct without a permit from the FWS or NOAA, as appropriate.

Federal agencies conducting rotenone projects in waters with threatened and endangered species need to determine whether such projects will affect listed species. The agencies may contact their local NOAA office and FWS Ecological Services offices at www.fws.gov/offices/ for assistance in fulfilling their Section 7 requirements. Non-federal entities conducting rotenone projects in waters with federally listed species, should contact their local Ecological Services office to determine whether a take permit is required prior to commencement of their work (refer to the above website for links to local offices). Contact should be made approximately six months in advance of the planned rotenone application dates since a significant review is required before a permit can be issued.

Federal and state agencies conducting rotenone projects in waters with threatened and endangered species will need to contact their local NOAA and FWS offices for direction on how they wish to permit these projects. Depending on circumstances—including existence of a federal nexus and likelihood of "affect," permission may be obtained under authority of different portions of the Act—including Sections 4(d), 6, 7 or 10.

2.2.5 Public and Agency Issue Identification and Notification

Concurrent with the environmental analysis process and compliance with the ESA and CWA, are the identification of issues from the public and affected agencies. The resolution of these issues through alternatives and mitigation will refine/redefine the project description. Often, monitoring to ensure that mitigation has reduced impacts and that regulatory requirements have been met result from issue identification and notification. Public involvement through a well-designed Public Involvement Plan will assist in getting meaningful input from the public (see Sections 1.7 and 2.1.1).

Agencies with regulatory authority (discretionary approval) over rotenone use are considered responsible agencies. In addition to the fish and wildlife agency proposing the use of rotenone, these agencies may include EPA and state or provincial departments of food, agriculture or pesticide regulation, public health, natural resources (i.e., forestry, lands, and parks), water quality, and environment. The use, registration,

and control of pesticides in the United States ultimately rest with EPA. State or provincial departments that regulate pesticides, food, or agriculture enforce pesticide laws and issue licenses and certificates for pest control operations. Many states require that a state licensed Agricultural Pest Control Advisor make a recommendation to use rotenone. Only a state licensed, qualified applicator (i.e., Certified Applicator) can supervise the application of rotenone. Agencies that regulate pesticides generally enforce regulations on safety gear and procedures, disposal of used pesticide containers and dead fish, and the potential effects on non-target species including humans.

State or provincial departments of health services often cooperate with the pesticide regulatory agencies in investigations of pesticide-related illnesses and develop employee safety standards for handling pesticides. Health agencies have also been delegated by the EPA to enforce the Federal Safe Drinking Water Act (1966 amendments) through such measures as adoption of drinking water standards and monitoring regulations. Public health concerns expressed by agencies over the use of rotenone have included (1) nuisance of flies and odors created by decaying fish, (2) consumption of dead fish containing bacteria and residues of rotenone and other compounds, (3) consumption of drinking water containing residues of rotenone and other compounds, (4) inhalation of pesticides, and (5) pesticide odors.

State or provincial departments of water quality or the environment typically issue required NPDES Permits, regulate storage and transport of hazardous wastes, disposal sites for pesticide containers, and water quality standards. Water quality and environmental agencies may establish water quality control plans that reflect water quality objectives for specific hydrologic basins. Concerns with rotenone use from environmental agencies have included (1) impacts on beneficial uses of water, (2) maintenance of water quality standards, and (3) impacts on aquatic life other than fish. Rotenone treatments may also affect the activities and interests of other agencies such as counties, cities, reclamation districts, irrigation districts, and other resource agencies.

Consult the plans of water quality, land management, and environmental agencies including the FWS, FS, Bureau of Land Management, and other affected agencies to ensure their existing management plans are considered.

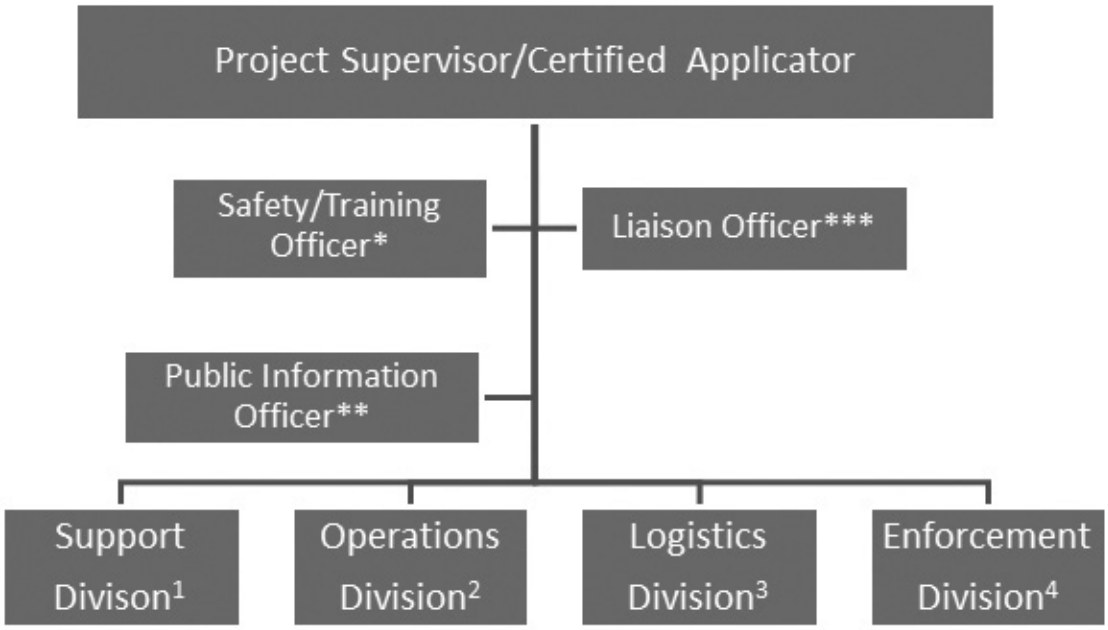
2.3 Project Implementation and Management

The last stage before treatment is to finalize plans for all operations associated with the project. A project schedule and structure are needed to organize large projects. For large, complex, or controversial projects, you may wish to employ a version of an Incident Command System (ICS) to organize the various functions (see Figure 2.2). For some treatments no ICS may be needed, while others may require many of the ICS's functional elements. Regardless of the structure chosen, qualified personnel (i.e., Certified Applicator) knowledgeable of rotenone and trained in planning and executing successful projects must supervise the treatment. Administrative approval for the treatment is obtained from the highest possible level in the natural resources agency commensurate with the scope of the project, ensuring adequate agency review. Assignments should be made for completing the project-specific work plans by specific dates. Each plan should contain sufficient information and detail so others can use the plan and complete the needed activity without assistance. The agency should complete all plans at least one month before treatment to allow for sufficient review and approval time. Also, the agency should ensure that all approvals from other agencies have been obtained and documented (see Section 2.1.4).

Depending on the size, complexity, and location of the treatment, plans may be needed for some or all of the following operations listed below. All of the SOPs in this manual provide information critical for successful planning, and these are referenced below with the relevant plan.

2.3.1 Rotenone Application Plan

Two SOPs describe the use of bioassays to help properly select treatment levels (SOP 5.1) and to monitor the efficacy of treatments (SOP 14.1). Five SOPs address specific delivery techniques and methods: the de-



*Safety/Training Officer is responsible for providing safety training to crew, issuing PPE, monitoring safety, and developing a spill contingency plan.
**Public Information Officer is responsible for communicating with general public and news media.
*** Liaison Officer is responsible for communicating and coordinating with other agencies.
[1] Support Division services and maintains sentinel fish, conducts project monitoring, and collects, measures and disposes of dead fish.
[2] Operations Division includes the application team and deactivation team.
[3] Logistics Division is responsible for obtaining, maintaining, and distributing all equipment and supplies.
[4] Enforcement Division supplies and operates the radio communication system and provides site security including restricted access to project area.

FIGURE 2.2. Suggested ICS structure under the Project Supervisor (Certified Applicator) and division of labor for a typical rotenone project.

sign and operation of semi-closed probe systems for application of liquid rotenone (SOP 8.1), operating protocols for the application of powdered rotenone (SOP 9.1), techniques for the application of liquid rotenone to streams, rivers, lakes and ponds (SOP 11.1), an operating protocol for spray application of pre-diluted liquid rotenone (SOP 12.1) and the preparation and use of after-market rotenone mixtures (SOP 13.1).

Lentic waters application plan would typically contain the following:

- Treatment rate
- Map showing the division of the lake treatment area into manageable quadrants (surface area, volume, and rotenone quantity) for treatment within 2 days
- Map showing inlets and outlets needed for treatment and deactivation with areas that will require special handling such as spring, seeps, and weeds
- Boats, equipment (pumps, hoses), crew, and rotenone needed for the 2-day treatment
- Access locations, logistics, and scheduling

Lotic waters application plan would typically contain the following:

- Treatment rate
- Map showing the division of the stream treatment area into manageable sections (location of drip stations, etc.) for treatment within 4 to 8 hours

- Map showing tributaries and outlet for treatment and deactivation with areas that will require special handling such as springs and seeps
- Drip cans, sprayers, equipment, crew, and rotenone needed for the 4- to 8-hour treatment
- Access locations, logistics, and scheduling

2.3.2 Deactivation Plan

SOP 7.1 provides guidance for determining the need for deactivation and methods for applying potassium permanganate and SOP 14.1 describes the use of in-situ bioassays to monitor efficacy of deactivation efforts. SOP 6.1 provides a description of the treatment and project areas. The deactivation plan would typically contain the following:

- Map showing locations of the deactivation site (primary and secondary dispensing devices) and deactivation zone taking into consideration the distance from treatment area, natural barriers, and downstream receiving waters
- Monitoring methods and schedule for measuring permanganate residuals and fish toxicity
- The triggers for beginning and ending of deactivation
- Anticipated potassium permanganate needs and duration of the deactivation
- Crew required for round-the-clock deactivation including dispensing permanganate and monitoring fish toxicity and permanganate residues
- Equipment, PPE, personal gear, electrical, and communication requirements

2.3.3 Site Safety and Security Plan

SOP 2.1 provides recommended supervisory training and qualifications while SOP 3.1 provides guidance on safety training and hazard communication for those involved in rotenone application. SOP 1.1 provides a protocol for posting treatment area restrictions prior to, during, and following the application of rotenone. SOP 4.1 provides protocols for safe storage and transport of rotenone and the specifics for a spill contingency plan. SOP 10.1 provides guidance on proper and safe procedures for transferring liquid rotenone from product containers to service containers and application equipment. The site safety and security plan would typically contain the following:

- ICS for the rotenone project (see Figure 2.2)
- Method of communication among crew and their contact information
- Safety training and hazard communication for project crew (see SOP 3.1)
- Minimization of worker (PPE) and public (restricted access and re-entry interval) exposure to chemicals
- On-site storage and staging areas and spill contingency plan
- Identification and posting of emergency medical care
- Identification of security apparatus and enforcement
- Internal and external communication

2.3.4 Monitoring Plan

SOP 16.1 provides guidance on monitoring requirements for drinking water and aquaculture, including wells, and the analysis of water for rotenone concentrations that are required on the label and possibly the NPDES permit. SOP 14.1 discusses the use of in situ bioassays to monitor the survival of fish (efficacy of rotenone) in the treatment area and downstream of the deactivation station (efficacy of potassium permanganate) that is required on the label and possibly the NPDES permit. Chapter 3 provides guidance on other biological sampling and monitoring techniques that are not required on the label for rotenone products but may be

required on NPDES permits. The benefits of monitoring in addition to the legal requirements are to ensure efficacy of both the application and deactivation of rotenone, limit potential litigation, assess resource impacts and recoveries, and assuage public fears. The monitoring plan would typically contain the following:

- Regulatory limits for the treatment including the allowable discharge levels of rotenone and toxicity
- Map showing the locations for the collection of samples
- Sampling and handling protocols, schedule for collection of samples, and prescribed methods of analysis and their minimum detection limits
- Procedure for completing a chain-of-custody to accompany the samples for analysis
- Personnel, equipment, and supplies for the monitoring

2.3.5 Other Plans

The four plans described above represent the minimum necessary for a project that requires rotenone deactivation. Depending on the complexity and size of the project, it may be beneficial to partition out some of the activities in these four plans to separate plans for better focus. Separate plans might be written for fish rescue, dead fish collection and disposal, communication, restocking, security, and safety.

2.4 Treatment

The planning process outlined in Sections 2.1 through 2.3 should have prepared the natural resources agency technically, politically, and legally for the rotenone treatment. Adhering to the rotenone label and the guidance offered in SOPs 1.1 through 16.1 in Chapter 4 will ensure a successful treatment. Understanding the techniques for rotenone use will provide a sound foundation for planning a treatment. It is imperative that these planning activities occur before treatment. The treatment occurs at the end of the planning process. Once the treatment has begun, the success of the project-specific work plans in meeting objectives should be monitored and, if necessary, amended to achieve the necessary objectives. It is not the plan itself that is important but the planning process that allows for a successful treatment.

2.5 Project Critique

2.5.1 Short-term Assessment

The agency should analyze the immediate effectiveness of the treatment and any mitigation measures. Goals for the short-term assessment include (1) determination of the effectiveness of chemical application (i.e., distribution and deactivation of rotenone), (2) determination of when the public can reenter the treatment area and resume use of water for drinking and irrigation, and (3) recovery of baseline environmental conditions before stocking fish. All personnel should be debriefed as soon as the treatment phase of the project has been completed to identify problems, determine causes, and propose corrective measures for future treatments. This effort involves the assessment of chemical and biological monitoring data and review of notes and observations recorded during and immediately following the treatment.

2.5.1.1 Assess the effectiveness of treatment and deactivation

The assessment of the effectiveness of the treatment and deactivation operations will enable project leaders to adjust plans based on the actual results. The effectiveness of these operations and related mitigation efforts can be judged as follows:

- Counts of dead fish in treatment area
- Mortality of sentinel fish in cages (see SOP 14.1)

- Bioassays with treatment area water
- Sampling for the presence of live fish
- Measurement of rotenone water concentrations in treatment and deactivated areas (see SOP 16.1) and measurement of permanganate residual in deactivation area (see SOP 7.1)
- Visual observations.

The sampling of baseline environmental conditions and estimates of dead fish from shoreline counts (lentic treatments) or collections from block nets (lotic treatments) are useful in evaluating the effectiveness of the treatment and deactivation. In lotic treatments, block nets and sentinel fish in live-cages placed at various intervals downstream from the deactivation station are effective in determining the point at which complete deactivation has occurred and therefore the extent of the actual impact zone. Real time data on sentinel fish survival can be used to adjust treatment and detoxification rates, and real-time data on permanganate residuals can be used to adjust deactivation rates.

2.5.1.2 Recovery of baseline environmental conditions

If baseline levels of nontarget species and environmental conditions were evaluated before the treatment, the agency needs to evaluate these parameters after the treatment to determine if recovery objectives were met and if mitigation measures are needed. Survival and recovery of the aquatic community may be demonstrated by sampling plankton, macroinvertebrates (aquatic insects, Crustacea, leeches, and mollusks), and amphibians (frogs, tadpoles, and larval and adult salamanders).

Before restocking, the agency needs to test the receiving water to determine if rotenone has been sufficiently deactivated or has dissipated adequately to assure survival of stocked species. While chemical testing is recommended, it is also a label requirement that live-cages containing the species to be restocked be used. The cages need to be placed in representative locations and in areas where test fish will not be killed by stress or some event unrelated to the treatment (e.g., vandalism, predation, temperature). The agency should be wary of embayments, bayous, backwaters, or deep-water zones that may still harbor pockets of toxic water. In stratified lake environments, the cages should be placed at depths where there is adequate oxygen for test fish to survive. If the fish survive for 24 hours it is permissible for restocking to occur.

2.5.1.3 Written critique

A written critique may be the most significant part of the treatment, and if properly done will assist the agency in improving planning and implementation of future projects. The agency should prepare a written summation and critique of the treatment as soon as possible after the treatment has been completed taking in consideration legal requirements and constraints. The agency should solicit input from all personnel involved in the treatment. It is advisable to have a meeting of all those involved in the treatment to get consensus on what worked and what should have been done differently. Each implemented plan from Section 3.3 should be assessed for accomplishing stated objectives. The agency should determine if the plan was followed, what problems or issues were associated with the plan, and what improvements were needed. The agency should send a draft of the written summation and critique to all personnel involved for review and consensus before completion of the final critique. When appropriate, the agency should use the critique to update policies and procedures.

2.5.2 Long-term Assessment

Following the treatment, the waterbody should be monitored for the presence of target fish using techniques such as electrofishing and eDNA before eradication is considered successful. An interval of 3 years following the final treatment is recommended to ensure that all target fish have been removed from the

area, even if a combination of electrofishing and eDNA monitoring are used. This is because physical removal techniques including electrofishing have efficiency bias and negative results are not conclusive evidence of the absence of target fish. Monitoring the eDNA of the target species may be used as an alternative to electrofishing when verifying that eradication is successful, but eDNA has efficacy limitations as well in determining the presence/absence of species (Baldigo et al. 2017; Wilcox et al. 2016). Due to uncertainties in the detection probability when using these methods, higher levels of confidence can be gained by sampling over multiple years, increasing sampling density, or using eDNA in conjunction with electrofishing. In addition, the agency should analyze the long-term effectiveness of the project by evaluating success at achieving stated objectives over time (5–10 years or more). This is important because a treatment that achieves its immediate goal of eradication or suppression may fail to meet management objectives over the long-term. Examples of failure include illegal movement of fish back into the treated area, failure of physical barriers that isolated a species being restored, or sport fish restoration efforts where the restored species fails to meet management objectives such as size or abundance. Measures that the long-term assessment should evaluate include (1) determination of the treatment permanence and benefits, (2) determination of the success of the mitigation measures in lessening the environmental impacts from the treatment, (3) assessment of the public perception of the success of the project, and (4) an overall assessment of the project.

2.6 References

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3 Biological Sampling and Monitoring

3.1 Purpose and Need

Biological monitoring of non-target organisms is not a label requirement, but it may be a Pesticide General Discharge (i.e., NPDES) Permit requirement. Monitoring can provide an understanding of the impacts of rotenone on non-target organisms, the time needed for recovery, and in an adaptive management fashion, can help inform future treatments to minimize impacts. Moreover, the strategy of minimizing non-target impacts is consistent with the recognized need for rotenone stewardship (Section 1.8).

3.2 Sample Design and Resource Considerations

The before-after-control-impact (BACI) sample design (Stewart-Owen et al. 1986) is well suited to detecting changes due to piscicide treatments. Through the establishment of control site(s) and sampling before and after the treatment, it is possible to distinguish natural variation from treatment impacts. If deactivation with $KMnO_4$ is part of the project, then Treatment Areas and Deactivation Areas should be considered separate "impact" areas and should be sampled independently. For control sites to accurately portray baseline conditions they must be carefully selected to match habitat of the impact areas and be exposed to similar weather and flow conditions. Parker and Wiens (2005) give a good summary of the issues to consider when designing a sampling scheme, including single versus multiple year sampling, and the appropriate timescale of sampling as dictated by spatial and temporal dynamic equilibria of populations.

Departures from the BACI sample design (e.g. no control areas or no before sampling) will have reduced explanatory power, and if used must be done with a recognition of the shortcomings (Ken Pollock, North Carolina State University, personal communication). Some of these are described below:

- Sampling only the treatment area and only after the treatment: Using this approach, the researcher would have to base any conclusions of change in the system on a subjective view of what the population or community was like before. Some understanding could be gained by studying the recovery process through a monitoring program into the future and looking at the time series of responses.
- Sampling only in the treatment area but both before and after the treatment: This approach gives the researcher an idea of baseline conditions before the treatment, but lacks the power to separate the response from that of long-term changes, such as weather-related perturbations (e.g., hydrograph, temperature). This may be the only reasonable design where control sites are unavailable.
- Sampling in both control and treated areas, but only after the treatment: This approach may be confounded by inherent differences that may exist between control and treated areas. This approach can be strengthened by matching the control and impacted sites as much as possible. This may be the best alternative if populations were not studied earlier and/or the treatment was unplanned (e.g., responding to an emergency such as an invasive species).

At its most robust, BACI sampling incorporates replicate and multi-year sampling. Many rotenone treatments however are not planned years in advance, nor are they accompanied with the budget necessary to do this type of sampling. Therefore, it may be possible to only take a single set of samples at each site pre-treatment and/or post-treatment to assess impacts. If replicate samples are taken at each site, it still allows for a measure of variation associated with the estimate of change due to the treatment. However, if the variance measurement comes from only one point in time, there is considerable potential for committing either type I or II statistical errors.

Another consideration is that the impacts of rotenone on many non-target organisms have already been well documented, and therefore the rigor with which these impacts need to be monitored will vary with the

scale of the project, the presence of listed or sensitive species, and social or legal constraints. An example of a three-tier approach for sampling benthic macroinvertebrates (BMI) is presented below which incorporates many of these factors (Table 3.1). Category 1 sampling would be employed in situations where no listed or sensitive species are present, no controversy is expected, and simply provides some basic indication that populations rebound. Category 2 sampling would be used in situations where listed or sensitive species are present or where concern has been raised about the impacts to BMI, the impacts of diminished BMI on fish after restocking, or additional research needs are determined. Category 3 sampling would be used where legal or regulatory action has been threatened regarding the impacts to BMI, or when the goal is to statistically validate impacts.

3.3 Temporal and Spatial Considerations for Sampling

The selection of sample sites to evaluate impacts from a rotenone treatment must be done recognizing that the application of rotenone and $KMnO_4$ will be uneven throughout the Treatment and Deactivation areas, and thus will also be the level of exposure to the chemicals, both in terms of concentration and duration. In stream treatments, rotenone concentrations will decline with increasing distance downstream from drip stations (Skaar et al 2017). Similarly, in the Deactivation Area, $KMnO_4$ concentrations will diminish with distance from the dispensing device, but will rise over time as the oxygen demand of the streambed materials is reduced. In standing bodies of water, the time it takes rotenone to mix thoroughly to a homogenous concentration will be quite variable, and dependent upon the shape and depth of the lake, presence of a thermocline, and wind action.

The uncertainty over how much rotenone or $KMnO_4$ the organisms will be exposed to should inform decisions regarding sample site selection. For example, if the before and after comparisons are intended to test the null hypothesis that densities of an organism do not change as a result of the treatment, then replicate samples should be confined to a geographical space where large variations in chemical exposure (and response to the exposure) are not expected. These sites should be selected in advance so that water samples can be collected during the treatment to determine the level of exposure to the chemical. This concern is less relevant when the organism studied is mobile and may have moved during the treatment. But in the case of stream benthic macroinvertebrates, any study seeking to quantify the impacts of exposure to one of these chemicals is most defensible if accompanied by measurements of rotenone concentration during the treatment. This is especially critical when comparing to other treatments. It is not sufficient to simply report the calculated or theoretical level of exposure without acknowledging that this has not been analytically confirmed.

3.4 Sample Metrics

Aside from fish, non-target aquatic organisms that might be affected by exposure to rotenone, both directly and indirectly through the removal of fish, include the benthic macroinvertebrates, zooplankton and gill-breathing amphibians. For the first two groups, they typically comprise complex communities with member species expressing different sensitivities to rotenone. Following the treatment, further changes may occur in the abundance of individual species due to species interactions within the altered community. Therefore, using individual species to characterize the impact of rotenone on the entire insect or plankton community may be misleading, and community metrics (see below) are more appropriate. For amphibians, the communities are simpler and attributing the changes in individual species abundance to rotenone exposure alone is more reliable.

3.4.1 Benthic Macroinvertebrates (BMI)

A fundamental difficulty with sampling these organisms (particularly in lotic environments) is the large number of species that may be present, some very abundant, others very rare, and in different habitats.

Table 3.1. A three-tiered approach for sampling benthic macroinvertebrates (BMI).

Category	Sample Locations	Sample Dates	Sample Gear & Size	Metrics
1	Control & Treatment (same stream)	• No more than 1 month pre-treatment • 1 year post-treatment	Kick samples (1 kick within each of 3 sites in Treatment & 1 kick at 1 Control)	• Taxa richness • EPT* indices • CPUE • Identify to lowest practical taxonomic level
2	Control, Treatment & Deactivation (same stream)	• 1-year pre-treatment & no more than 1 month pre-treatment • 1 month post-treatment, pre-runoff the following spring, and 1 year post-treatment	Use EPA EMAP** sampling & analysis protocols with 3 sites in Control, Treatment & & Deactivation	• Taxa richness • EPT indices • CPUE from kick, density estimates from Hess/Surber • Functional metric (% predator) • Habitat metric (% burrower) • Composition metric (%EPT, % non-insects) • Richness metrics (E taxa, P taxa)
3	Control, Treatment & Deactivation; Control is a neighboring untreated stream with similar habitat, elevation, flow, weather, etc.	Multiple-previous year (multi-season) & muliple post-year (multi-season)	Use EMAP sampling & anaylsis protocols designed to achieve some statistical level of significance (QA/QC)	Consult with taxonomist for relevant metrics and indices relevant to site & treatment conditions; build a reference collection, have independent taxonomists identify all samples (including the 10% subset of samples) & identify to lowest practical taxonomic level

* EPT = Ephemeroptera, Plecoptera, Trichoptera

**Available online at https://archive.epa.gov/emap/archive-emap/web/pdf/ewwsm_s11.pdf

Therefore, trying to do a complete inventory can be almost impossible, especially if the amount of habitat sampled is small relative to total habitat. This was demonstrated by Vinson et al. (2010) who sampled BMI monthly in the Logan River, Utah for 10 years. While the number of taxa in monthly samples remained constant, the total number of accumulated taxa continued to rise, even after 10 years. Therefore, unless there are rare, "sensitive" or endangered species that need to be monitored, it is best to portray BMI through commonly used community metrics such as taxa richness, EPT taxa richness, Shannon or Simpson diversity indices, and functional feeding group ratios (Carter et al. 2007). These incorporate the abundance and presence/absence of many species, thereby dampening the influence of any one species. The indices are also better measures of whether the community is still functioning, which may be more meaningful to the general public or angler groups who are concerned about ecological disruption or anxious to resume their activities on the water.

Biologists monitoring BMI should search databases from natural resource agencies, colleges, and universities to determine if federally endangered or state-listed "sensitive" species are known to exist in the Project Area. More likely, records may exist which are for the same drainage, but not the exact lake or stretch of stream being treated. If so, preliminary sampling of the Project Area is warranted. If the species of concern is found in the Project Area, consider mitigation measures to protect the species, such as treating when adults have emerged or removing individuals and holding them in clean water during the treatment and releasing them back afterwards. Another option would be that if other nearby sources of the species exist, it may be possible to use them as a donor population for the system after treatment. Skorupski (2011) found that insect taxa responded uniquely to a stream treatment and began drifting after different durations of exposure. Some of the individuals may survive if they drift down below the Project Area, but the extent to which this may occur is unknown. If survival of endangered or sensitive species is of particular concern, the collection of these individuals in the drift downstream of the Project Area may be seen as a positive outcome of the treatment and should be documented.

3.4.2 Amphibians

The larval, gill-breathing forms of amphibians are more sensitive to rotenone than the adult forms, and some later-stage larval forms are also less sensitive than earlier forms because they switch to mouth breathing (Billman et al. 2011). Because of these differences, it is imperative that the life stage is noted when recording amphibian observations or collections. Similarly, the dates when less sensitive life stages are present is important to know so that treatments may be timed to avoid impact. Gosner (1960) provides drawings of the life stages for tadpoles, and these should be used to describe collected animals.

It is important to do surveys of amphibians in nearby waters and wetlands to understand the presence and abundance of all species both before and after a treatment. This is because some adults may leave the water during the treatment and move to these untreated waters, and these same waters may serve as a source of recolonization following a treatment.

Fish may prey upon amphibians in certain circumstances (Billman et al 2012), and it is important to account for this impact when measuring recovery from a rotenone treatment. Therefore, one might expect that amphibian abundance will increase immediately following a treatment, but then decline once fish are reintroduced. Habitat selection of amphibians may change as well, as they seek shelter to avoid predation. This will have implications for the timing of amphibian monitoring following a treatment, as well as the habitats which are sampled and the techniques most appropriate to sample those habitats. Graeter et al (2013) offers guidance for sampling amphibians.

3.4.3 Zooplankton

Some of these taxa (rotifers and protozoans) are fairly tolerant of rotenone exposure, while others (cladocerans and copepods) are very sensitive and will likely show a considerable decrease in abundance following a lake or pond treatment. Typically following a treatment, these latter two groups may disappear

totally from the water column, surviving as resistant (ephippial) eggs (Bradbury 1986). Within one to several months their populations will begin to rebound, and typically even exceed pre-treatment abundances, in part because of the abundance of phytoplankton on which to feed and the absence of planktivorous fish. Once fish are re-introduced to the waterbody, their abundance will drop to levels in keeping with the dynamics of interaction with algae and fish.

These quickly changing conditions will dictate more temporally-intensive sampling if the goal is to describe the recovery process. Sampling should be designed to measure abundance (or an index of abundance) of major taxonomic groups. The impacts of fish will also extend to the size structure of the zooplankton; the large *Daphnia* species in particular will likely show not just drops in abundance but diminishment of larger size classes. Sub-samples should therefore be used to characterize the size structure of the larger species or any that have been shown by previous diet studies to be utilized by fish species inhabiting the waterbody.

3.5 Sampling Equipment and Techniques

3.5.1 Benthic macroinvertebrates

Quantitative area samplers such as the Hess and Surber samplers can give precise estimates of benthic macroinvertebrate density, but will not be good at sampling rare species due to the small surface area they sample. In addition, they are limited to sampling in water depths less than 0.5 m. Kick nets are another type of sampling gear that can be used in water up to one meter deep, and consist of a net 1 m^2 in size attached to two poles, functioning similarly to a fish kick seine. Kick samples are described as semi-quantitative (Barbour et al 1999), because the area disturbed in front of the net is not precisely measured, but it may be able to build a bigger species list due to the greater surface area sampled (roughly 1 m^2 for the kick net compared with 0.2 m^2 for the Hess and 0.09 m^2 for the Surber). Hauer and Resh (2007) and Merritt and Cummins (1996) have descriptions of stream macroinvertebrate sampling equipment.

Sample location considerations should include knowledge of the habitats utilized by the different benthic organisms. As is typically the case when sampling to characterize rotenone impacts, it will be adequate to quantify overall community composition, meaning that you will be trying to sample all habitats in proportion to their availability. For streams, this will likely mean sampling in both riffles and pools, while in lakes, it will involve sampling both the littoral and profundal zones using clam-shell samplers like Eckman or Peterson dredges (Wetzel and Likens 2013).

3.5.2 Amphibians

The appropriate sampling techniques and equipment for amphibian sampling will depend on the sampling objectives. In many cases it will be sufficient to simply do an inventory of the species in the Project Area, where the sampling scheme does not need to include a randomized and/or standardized design (Graeter et al 2013) and would generally include using a diversity of capture techniques, sampling a diversity of habitats, and sampling during peak periods of activity. However, if a species of concern is known or suspected to be present in the watershed, then a more rigorous sampling approach may be needed, including site occupancy models, relative abundance, and population estimation. Graeter et al (2013) provide a comprehensive table of suitable sampling techniques for different amphibian and reptile species in different regions of the USA. Heyer et al (1994) and Olson et al (1997) provide useful sources of information on sample design and sampling techniques for amphibians.

3.5.3 Zooplankton

The best method and technique for characterizing impacts of a rotenone treatment will depend on the productivity and physical characteristics of the lake, including depth, and extent of littoral areas. Zooplankton are typically sampled using fine-mesh nets. Nets such as the Clarke-Bumpus variety are towed

horizontally behind a boat to sample a specific depth stratum of a lake and because of the large volume of water that is filtered, can be useful in unproductive waters. In more productive waters, nets pulled vertically from the bottom to the surface will collect an "integrated" sample of all depths of the water column. The horizontal sampling will yield volumetric density information (animals/cubic meter), while the plankton recovered from vertically pulled nets are normally portrayed on an aerial basis (animals/square meter). Volumetric samplers such as Schindler traps made of very fine mesh fabric or plexiglass can be useful in sampling all members of the plankton community including the rotifers (Wetzel and Likens 2013).

As mentioned previously, the thermocline in lakes may act to slow the movement of rotenone to greater depths and concentrations of rotenone in the water column and sediments of the epilimnion may be greater than in the hypolimnion. If trying to characterize the impacts of rotenone relative to these physiochemical features, then the sampling scheme should be adjusted accordingly.

3.6 References

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4 Standard Operating Procedures

The techniques for using rotenone are outlined in the following 16 SOPs. The information contained in each SOP in the *Rotenone SOP Manual* generally follows the order (1) title, (2) purpose, and (3) procedure. SOPs may be revised or new SOPs may be added and approved by the EPA in the future. Applicators should check the AFS website www.rotenone.fisheries.org frequently for changes. The reference to the revision is listed as SOP #.* (# is SOP number and * is revision number). Readers can submit comments to the AFS webpage.

The words "must," "should," "may," "can," and "might" have very specific meanings in these SOPs:

"Must" is used to express an absolute (mandatory) requirement, that is, to state that the guidelines are designed to satisfy the specified condition. "Must" is only used in conjunction with factors that directly relate to the legality or acceptability of specific recommendations (i.e., a requirement on the label of a pesticide product).

"Should" is used to state that the specified condition is recommended (advisory) and ought to be met, if possible. Terms such as "is desirable," "is often desirable," and "might be desirable" are used in connection with less important factors.

"May" is used to mean "is (are) allowed to."

"Can" is used to mean "is (are) able to."

"Might" is used to mean "could possibly." "Might" is never used as a synonym for either "may" or "can."

The 16 SOPs in this section of the manual are:

1.1 Public Notification and Treatment Area Restrictions
2.1 Supervisory Training and Qualifications and Regulatory Compliance
3.1 Safety Training and Hazard Communication
4.1 Rotenone Storage, Transportation, and Spill Containment
5.1 Treatment Rates and Strategies
6.1 Treatment Areas and Project Areas
7.1 Chemically Induced Deactivation
8.1 Semi-Closed Probe Systems for Application of Liquid Rotenone
9.1 Semi-Closed Aspirator Systems for Application of Powdered Rotenone
10.1 Transferring (Mixing/Loading) Liquid Rotenone
11.1 Drip Cans, Peristaltic Pumps and Propwash Venturi for Application of Liquid Rotenone
12.1 Sprayers for Applying Dilute Liquid Rotenone
13.1 Treatment of Seeps, Springs, and Upwelling Groundwater
14.1 In-Situ Bioassays to Monitor Efficacy
15.1 Collection and Disposal of Dead Fish
16.1 Monitoring Rotenone Concentrations in Surface and Ground Waters

Public Notification and Treatment Area Restrictions SOP: 1.1

PURPOSE:

1. Mitigate for human recreational exposure to rotenone
2. Provide an operating protocol for public notification of treatment area restrictions prior to, during, and following application of rotenone

PROCEDURE:

I. Press Release (recommended procedure)

Send general press releases to media outlets within the watershed and adjoining areas no more than 3 weeks and no less than 1 week in advance of treatment, or as required per individual natural resource agency and/or state law. Information includes:

- A description of the project area
- The reason for the treatment
- The name and concentration of the piscicide formulation used, and deactivation agent if applicable
- Any public or water use restrictions
- Posting procedures
- The date(s) of treatment and the anticipated length of time the area will be affected
- The names and contact information of designated applicator and/or agency contact person(s).

Media outlets include newspapers (print or online versions), radio and television stations, social media, and agency web sites.

Press releases are provided to the media for voluntary publication or for broadcast to the public. Press releases are also valuable as an information transfer when posted at public parks and beaches, boat launch sites, and bait and sport shops around the general treatment area.

Provide a copy of the news release to those immediately affected by the treatment such as residents, property or business owners or managers, and riparian users in or adjacent to the treatment area. Include those within a reasonable distance of the shoreline or stream bank affected by the rotenone treatment, including any waters treated with potassium permanganate to deactivate rotenone-treated waters. Notification by mail, email, or by handbills given directly is acceptable.

- Property owners can be determined by accessing county records, usually by tax parcel number
- Water rights holders can be determined by accessing records from the state or local water resources agency

II. Placarding of Treatment Area and Project Area (required per product labels)

A. Locations

1. The treatment area at public access points
   - Trailheads
   - Roads
   - Trails
   - Boat launches
   - Parking and recreational sites

2. **OR** a recommended minimum of every 250 ft (76 m) along treatment area

B. Time period (access sites posted 1 day prior to treatment and application sites posted at time of application)

- For both lotic (flowing water) and lentic (standing water) applications of ≤0.09 ppm (90 ppb) active rotenone (≤1.8 ppm 5% a.i. formulation), signs can be removed once application is complete.

- For flowing water applications >0.09 ppm rotenone (>1.8 ppm 5% a.i. formulation), signs can be removed following a 24-h bioassay demonstrating survival of bioassay fish, when analytical chemistry shows ≤0.09 ppm rotenone, or 72 hours after the application is complete, whichever is less.

- For standing water applications >0.09 ppm rotenone (>1.8 ppm 5% a.i. formulation), signs can be removed following a 24-h bioassay demonstrating survival of bioassay fish, when analytical chemistry shows ≤0.09 ppm rotenone, or 14 days after the application is complete, whichever is less.

- See SOP 14.1 for bioassay techniques and SOP 16.1 for analytical chemistry techniques for monitoring rotenone concentrations in water.

- Signs must remain legible during the entire posting period.

C. Required placard information (see 40 CFR for specifications)

- "DANGER/PELIGRO"
- "DO NOT ENTER WATER/NO ENTRE AGUA: Pesticide Application"
- The name of the product applied
- The purpose of the application
- The start date and time of application
- The end date and time of application
- "Recreational access (e.g., wading, swimming, boating, fishing) within the treatment area is prohibited while rotenone is being applied."
- "Do not swim or wade in treated water while placard is displayed."
- "Do not consume dead fish from treated water."
- The name, address, and telephone number of the responsible agency or entity performing the application.

D. Acceptable placard materials to withstand 14 days exposure:

- Heavy waterproof stock
- Laminated in plastic
- Hard plastic
- Metal
- Wood

Supervisory Training and Qualifications and Regulatory Compliance
SOP: 2.1

PURPOSE:

1. Mitigate for occupational and environmental exposures to rotenone
2. Provide recommended supervisory training and qualifications enabling the successful planning and execution of a rotenone project
3. Clarification on rotenone label and Safety Data Sheet (SDS) compliance

PROCEDURE:

I. Training Program for Rotenone Application

Certified Applicator supervising any aspect of the application of the project should receive training on the *Rotenone SOP Manual*. Authorized training is available as a 4½-day course entitled *Planning & Executing Successful Rotenone and Antimycin Projects* through the American Fisheries Society at https://fisheries.org/membership/continuing-education/. The course is typically offered at Utah State University, Logan, in May prior to Memorial Day. The course has also been specially offered at other times and locations in cooperation with state fish and wildlife agencies. State pesticide licensing agencies have approved this course for Continuing Education credits.

Additionally, a project supervisor should have participated in all planning and field aspects of a minimum of two previous rotenone projects and have supervised a minimum of one aspect of a previous application prior to supervising a rotenone project.

II. Project Supervisor Qualifications and Responsibilities

- Possess a valid Certified Applicator Certificate or license issued by respective state, territorial or tribal authority and be able to remain on site for the duration of the application.
- Be familiar with application and deactivation equipment and techniques.
- Ensure that the application and personnel are in compliance with both FIFRA and the product label (see FIFRA and Label Compliance below) and with Occupational Safety and Health Administration (OSHA) (see OSHA Compliance below).
- Provide safety training, safety training records, and personal protective equipment in a state of good repair for project personnel (see SOP 3.1).
- Develop strategies for fish sampling/control/eradication that reflect sensitivities of target species, characteristics of rotenone, and important environmental conditions (see SOP 5.1).

- Develop preliminary, intermediate, and implementation and management plans for public involvement, application, deactivation, monitoring, and safety.
- Develop management and planning strategies that deal positively and effectively with unanticipated events before they occur. These incidents may involve the public and news media.
- Implement application and deactivation techniques that minimize impacts to non-target organisms.
- Explain rotenone label and SDS contents and requirements and how these affect use and protect human and environmental health to project personnel and the general public.
- Characterize effects on target and non-target organisms and environmental fate of rotenone under specific treatment conditions and communicate that to project personnel and the general public.
- Describe key environmental laws, regulations, and processes and how these affect the specific use of rotenone to project personnel.
- Have command of water chemistry and temperature, water travel time, discharge measurements, kinetics of deactivation, use and operation of all equipment, on-site toxicity, and safety procedures and equipment.

III. FIFRA and Label Compliance

EPA regulates the use of pesticides under the authority of two federal statutes: the FIFRA and the Federal Food, Drug, and Cosmetics Act (FFDCA). The regulations implementing the intent of FIFRA can be found in CFR Title 40. FIFRA provides the basis for regulation, sale, distribution and use of pesticides in the United States. FIFRA authorizes EPA to review and register pesticides for specified uses. EPA also has the authority to suspend or cancel the registration of a pesticide if subsequent information shows that continued use would pose unreasonable risks. When a material is registered as a pesticide there is a presumption that there are no unreasonable risks to humans or the environment associated with the specified use. FFDCA authorizes EPA to set maximum residue levels, or tolerances, for pesticides used in or on foods or animal feed.

No one may sell, distribute, or use a pesticide unless it is registered by the EPA. The EPA must classify each pesticide as either "general use," "restricted use," or both. "General use" pesticides may be applied by anyone, but "restricted use" pesticides may only be applied by Certified Applicators or persons working under the direct supervision of a Certified Applicator. Applicators are certified by the state, territorial or tribal governments under a certification program approved by the EPA. All rotenone products are Restricted Use Pesticides and can only be applied by Certified Applicators trained in aquatic pest control, or persons under their direct supervision.

All pesticide label language must be approved by EPA before a pesticide can be sold or distributed in the United States. The rotenone labels contain critical information that should be discussed with

those applying the material including:

- Brand name and EPA registration and establishment numbers
- Restricted use statement (rotenone is a Restricted Use Pesticide)
- Ingredient statement
- Pesticide hazard class (signal word) and first aid instructions
- Precautionary statements (for humans and domestic animals) and PPE requirements
- Instructions for storage and disposal
- Registrant name and address
- Net weight or volume of container
- Instructions for use

The rotenone label provides instructions for its safe and effective use that should be discussed with those applying the material including:

- Treatment site
- Treatment concentration
- Treatment method
- Dilution instructions
- Treatment timing and frequency
- Re-entry interval

The overall intent of the label is to provide clear directions for effective product performance while minimizing risks to human health and the environment. **It is a violation of federal law to use a pesticide in a manner inconsistent with its labeling**. The courts consider a label to be a legal document. In addition, following labeling instructions carefully and precisely is necessary to ensure safe and efficacious use.

It is important that the user carefully study and fully understand the label and this *Rotenone SOP Manual*. When in doubt, the user should contact the manufacturer or their state pesticide regulatory agency. The *Rotenone SOP Manual* or an expert associated with the AFS (www.fisheries.org) can provide guidance, but these are not legal authorities. The SOPs in this manual provide guidance on a variety of procedures for storage and spill containment of rotenone products, determining appropriate treatment rates and strategies, operation of application systems for rotenone products, monitoring and deactivation. Individuals applying rotenone must do so in a manner not only consistent with federal laws, but also consistent with state laws and regulations, which differ from state to state. Additionally, the agency with primary responsibility for regulating pesticide use differs in each state. It is important to consult with the state pesticide regulatory agency to determine:

- If a particular rotenone product is registered for use in that state
- Rules and regulations governing pesticide use in that state
- Notifications or postings prior to pesticide applications
- How to become a certified pesticide applicator

The rotenone label and *Rotenone SOP Manual* must be available at each project site, and it is a violation of Federal law to use a pesticide product in a manner inconsistent with its labeling, including both the label and the *Rotenone SOP Manual*.

IV. OSHA Compliance

Occupational Safety and Health Health Administration (OSHA) regulates the safe and healthful working conditions for working men and women in the United States under the authority of the Occupational Safety and Health Act (CFR Title 29). In meeting this goal, OSHA has many rules and regulations which direct rotenone handling and storage. Among OSHA directives is the Hazard Communication Standard (HCS) which is based upon the premise that employees have both a need and a right to know the hazards and identities of the chemicals to which they are exposed. They also need to know what protective measures are available to prevent adverse effects from occurring. The HCS is designed to provide employees with the information they need. The HCS requires each employer to have a Comprehensive Hazard Communication Plan (CHCP) and to provide their employees with communication and training relative to all hazardous materials which they may encounter in their work place. The Safety Data Sheet (SDS), along with training and the product label are integral parts of the CHCP (available at: https://www.osha.gov/dsg/hazcom/index.html).

OSHA requires all rotenone registrants to obtain or develop a SDS for each hazardous chemical they produce or import. The data sheets include safety information generally applicable for safe handling and use which are known to the rotenone registrant and importer preparing the SDS, including appropriate hygienic practices, protective measures during repair and maintenance of contaminated equipment, and procedures for clean-up of spills and leaks. They also include appropriate engineering controls, work practices, and personal protective equipment (PPE). Employers are required to maintain in the workplace copies of the required SDS for each hazardous chemical and ensure that they are readily accessible to employees.

SDSs contain vital information that is important not only to those handling rotenone but also first responders in case of a spill or fire. Changes have been made to reflect the Global Harmonization System (GHS) for ten health hazard classes with ratings ranging from 1 to 4 **with 1 being the most hazardous and 4 being the least hazardous**. However, the physical hazards classes are still represented by the NFPA system with ratings ranging from 0 to 4 **with 4 being the most hazardous and 0 being the least hazardous**. It is imperative that all are familiar with the SDS information and have it available at all times. The information contained in an SDS includes:

- Product Identification (manufacturer's, name, address, and phone number, recommended use and restrictions on use)
- Hazard identification (ratings, hazard statements, and precautionary statements)
- Composition/Information on Ingredients
- First-Aid Measures (4 routes of exposure)
- Fire-Fighting Measures
- Accidental Release Measures
- Handling and Storage
- Exposure Controls/Personal Protection (PPE and safe exposure limits)
- Physical and Chemical Properties
- Stability and Reactivity
- Toxicological Information (acute and chronic)
- Ecological Information
- Disposal Considerations
- Transport Information
- Regulatory Information (pesticide labeling information)
- Other Information

As mentioned above, employers are required to have a CHCP to identify all chemical hazards to the employees. Employers are also responsible for instructing employees on how to handle and use pesticides and on how to comply with pesticide laws and regulations (see SOP 3.1).

As a general rule, an applicator must follow the product label when applying rotenone and should follow the product SDS for all other storage and handling procedures. Although there are OSHA requirements for the content of SDSs and employers are required to communicate hazards to their employees using the CHCP, the rotenone product label is approved by EPA and must also be adhered to. Rotenone product SDSs are not approved by OSHA or EPA. Employers are required by OSHA to keep records of any training. Consult with OSHA, the state OSHA or safety officer for more information.

V. Additional Information

Carnegie Mellon University, Environmental Health and Safety. Hazard Identification for new MSDS (SDS). Available: www.cmu.edu/ehs/fact-sheets/msds-hazard-identification-systems.pdf (June 2016).

Occupational Safety and Health Administration. OSHA Quick Card—Hazard Communication Data Sheets. Available: https://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html (June 2016).

University of California, Statewide Integrated Management Program. 2000. The safe and effective use of pesticides, 2nd edition. Agriculture and Natural Resources Publication 3344.

Safety Training and Hazard Communication
SOP: 3.1

PURPOSE:

1. Mitigate for occupational exposure to rotenone
2. Provide safety training and hazard communication to mixers, loaders, applicators, and others involved with the application of rotenone

PROCEDURE:

I. Safety Training

The EPA, under the authority of Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), enforces the Worker Protection Standard (WPS) that mandates pesticide-specific safety training every year for all employees involved in a pesticide application. Government agencies involved in pest control programs and control of vertebrate pests not related to production of agricultural crops are exempt from the WPS. However, this training is similar to the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200). This training could be part of the continuing education requirements for maintaining Certified Applicator licensing. As many states have differing safety training requirements, check with local authorities for current safety training requirements in your individual state.

Certified Applicators normally provide this training **annually** on how to safely mix, load, and apply rotenone as described on the label and in this SOP. Employees are given the training **before** working with rotenone. Rotenone is a Restricted Use Pesticide that can only be used by, or under the direct supervision of, a Certified Applicator who must remain present during its application. All the information in the training must be in written form and employees must sign a written record verifying the training as indicated in a Record of Pesticide Training (see Appendix A for example).

The training detailed in SOP 3.1 is based on the OSHA Comprehensive Hazard Communication Plan (CHCP) (requirements discussed at https://www.osha.gov/dsg/hazcom/solutions.html) that provides employees with identities and hazards of the chemicals they are exposed to while working on a rotenone treatment. Employers are responsible for employees handling and using pesticides in a manner consistent with labeling, laws and regulations and need to keep records (normally for 5 years) of certain written training materials (see Table SOP 3.1). Employees wearing respirators require extra training and medical certification that they are capable of wearing a respirator without causing physical stress. If the use of respirators is required as personal protective equipment (PPE), the employer must maintain a Respiratory Protection Program that includes medical evaluation, fit testing and training requirements (available at https://www.osha.gov/dte/library/respirators/major_requirements.pdf).

Table SOP 3.1. Summary of records employer must keep for pesticide training.

Information	Storage Location
Record of pesticide training	Employer's office site
Written training program	Employer's office site
Respirator program procedures	Employer's office site
Pesticide label & SOP Manual	Work site
Pesticide Safety Information Series	Employer's office site
Safety Data Sheet (SDS)	Employer's office site
Storage area posting	Storage area
Emergency medical care notice	Work site
Doctor's report for respirator use	Employer's office site
Pesticide use records	Employer's office site

II. Elements of CHCP

The CHCP for rotenone consists of the following:

- Verbal warning (see A below)
- Review of the rotenone product label and SOPs (see B below)
- Review of the rotenone product SDS (see C below)
- Instruction on application of rotenone (see D below)

Specifically, training must include the following:

- Potential health effects of rotenone
- What to do in an emergency and emergency care available
- PPE required for rotenone
- How to use rotenone safely
- Rights as an employee and where to find out more information on rotenone

Specific and up-to-date information needed for rotenone safety training and a Hazard Communication Standard program is available to those who attend the training program for the AFS *Rotenone SOP Manual*. Go to the AFS website www.fisheries.org/membership/continuing-education/ for a schedule of available classes. Rotenone safety information is also found on the SDS and the label of the rotenone product, and general information is found in the California Department of Pesticide Regulation Pesticide Safety Information Series (see Section III).

A. Verbal Warning

This consists of a verbal discussion of the information and warnings on the label, SOPs, and SDS for the rotenone product. The warning should be verbal since not all workers are able to read.

B. Rotenone Product Label and SOPs

When reviewing the product label and SOPs, the following information should be discussed with employees:

- What chemicals are in the rotenone product
- First aid and health warnings
- Proper use and maintenance of PPE required (see Table SOP 3.2)
- Directions for applying rotenone

Following the label and SOPs will result in the safe mixing and application of rotenone. The label and *Rotenone SOP Manual* must be at the project site (i.e., treatment area) where the rotenone is mixed and applied (see Table SOP 3.1).

Specifically, the directions for applying rotenone should provide instruction as appropriate on the following:

- Application site
- Dosage rate
- Application method and equipment
- Dilution instructions
- Application timing and frequency
- Restricted entry interval

C. Rotenone Product SDS (see SOP 4.1)

Specifically, the following should be discussed with employees:

- Health Effects—Information on how rotenone can affect health is found in the Hazards Identification (Section 2) and in Toxicological Information (Section 11) of SDS.
- What to do in an Emergency—Information on first aid and where to get emergency medical care is found in the First Aid Measures (Section 4) of SDS.

Table SOP 3.2. Summary of PPE requirements when applying liquid and powdered rotenone formulations (check product label for specific PPE requirements).

Liquid Formulations	Powdered Formulations
Coveralls over long-sleeved shirt & long pants[1]	Coveralls over long-sleeved shirt & long pants[1]
Chemical-resistant gloves	Chemical-resistant gloves
Chemical-resistant footwear & socks	Chemical-resistant footwear & socks
Protective footwear	Protective footwear
When spraying, a NIOSH approved particulate respirator with any R or P filter with approval prefix TC-84A (e.g., TC-84-2561)[2]	NIOSH approved particulate respirator with any N, R or P filter with approval prefix TC-84A or a NIOSH approved powdered air purifying respirator with HE filter with prefix TC-21C[3]

[1] Waterproof waders may be worn in place of coveralls, chemical-resistant apron & chemical-resistant footwear.
[2] The term "dust/mist respirator" is no longer used and replaced with the term "particulate respirator".
[3] Other respirator choices are available, consult the label.

- PPE—PPE is required for rotenone application (Table SOP 3.2). Information on the need to wear PPE, how to take care of PPE and what PPE can and cannot protect is found in Exposure Controls/Personal Protection (Section 8) of SDS.
- Pesticide Safety—Information on the meaning of safety statements and safety rules for handling pesticides (e.g., *Pesticide Safety Information Series* listed under Additional Information III).
- Employee Rights and More Information—Job safety information, safety leaflets, SDS and SDS Pocket Dictionary informs the employee about the pesticide and its dangers. Each employee has the right to know when and where the pesticide was applied, the name of the pesticide and the EPA registration number.

D. Application of Rotenone

Provide instruction on how all application equipment work, application timing and calibration, and the proper use of PPE on the product label.

III. Additional Information

California Department of Pesticide Regulation. 2013. Pesticide safety training for employees handling pesticides. Available: http://www.cdpr.ca.gov/docs/enforce/cmpliast/bkltmenu.htm. (March 2018).

California Department of Pesticide Regulation. 2015. Pesticide Safety Information Series PSIS N 1-8. Available: http://www.cdpr.ca.gov/docs/whs/psisenglish.htm. (March 2018).

EPA. 2016. Revisions to the Worker Protection Standard. Available: https://www.epa.gov/pesticide-worker-safety/revised-certification-standards-pesticide-applicators. (March 2018).

Appendix A

Rotenone Product _____ [1] Safety Training Record

This is to certify that _____has received _____hours of rotenone safety training.

Employee Signature_____

Employee Title_____

Employee Work Location_____

Trainer_____Date_____

Subject Areas for Annual Training:

Safety Procedures: personal protective equipment, engineering controls, equipment, and heat-related illness
Rotenone Labeling (labels and AFS Rotenone SOP Manual): signal words, precautionary statements, first aid instructions, mixing and application instructions
Rotenone Handling Procedures: container handlings, mixing and application equipment and techniques, and triple rinsing containers
Routine and Emergency First Aid and Decontamination
Emergency Procedures: medical care and non-routine tasks or emergency situations such as spills or fire
Common Symptoms of Rotenone Overexposure: common, acute, chronic, delayed, and sensitization effects
Environmental Concerns: such as drift, runoff, and wildlife hazards
Laws and Regulations: applicable laws and regulations, SDS, Pesticide Safety Information Series, label requirements
Employee Rights: information on pesticides they may be exposed to, rights against discharge or other discrimination due to exercise of these rights
Location of Documents: Hazard Communication Program, pesticide use records, Pesticide Safety Information Series leaflets, SDS and training records

[1]Insert the specific Brand Name of the rotenone product.

Appendix B

Pesticide Training &
Hazard Communication
for

CFT Legumine

Required Pesticide Training

- Health (immediate & long-term) effects
- Environmental concerns
- Pesticide label, SDS, laws & regulations
- What to do & where to go in an emergency
- Personal Protective Equipment (PPE)
- Pesticide safety & handling procedures
- Employee rights & where to find information on pesticides

Pesticide Laws & Regulations

- Registered pesticides
  - Federal EPA registration
  - State registration
- 40 CFR – EPA (FIFRA)
- 21 CFR – FDA (pesticide residues)
- 20 CFR OSHA (worker health and safety)
- Failure to comply w/ label –misdemeanor
  - Criminal (intentional or negligent)
    - Up to $5,000
    - 6 months jail
  - Civil (unintentional) – up to $25,000
  - Administrative remedies – license revoked

Pesticide Label & SDS

- Pesticide label
  - Specific information required
  - Approved by EPA under authority of FIFRA
  - Legally enforceable application directions
  - AFS Rotenone SOP Manual is labeling
- Pesticide SDS
  - Specific information if available
  - Must be in specific format
  - Vehicle of communication
  - Manufacturing, storage & transportation activities

Section I

Potential Acute & Chronic Effects

- Rotenone is a botanical compound
- Powdered & emulsifiable formulations
- Found in roots in bean family
- Used for centuries for gathering fish for food
- Fish management tool since ≈ 1930s
- Mode of action – phosphorylation inhibitor
- Mitochondria → Cell → Organ → Organism

Mammalian Toxicity & Signal Words (acute lethal oral dose)

LD50 (mg/kg)	Toxicity Rating	Toxicity Category	Signal Word
≤ 50	I	Highly toxic	DANGER / POISON
51 – 500	II	Moderately toxic	WARNING
501 – 2000	III	Slightly toxic	CAUTION
> 2000	IV	Practically nontoxic	CAUTION

Rotenone & Rotenone in CFT Legumine Acute Toxicity Profile

Toxicity Value	Toxicity Category	Signal Word
Rat Oral LD50 102 mg/kg (M) 39.5 mg/kg (F) 320 mg/kg (F) - CFT	II I II	WARNING POISON/DANGER WARNING
Rabbit Dermal LD50 > 5000 mg/kg	III	CAUTION
Rabbit Dermal Irritation PIS 0.08	III	CAUTION
Rabbit Eye Irritation PIS 3.3	III	CAUTION
Rat Inhalation LD50 0.024 mg/L (M) 0.019 mg/L (F) > 0.062 mg/L (M&F) - CFT	I I II	POISON/DANGER POISON/DANGER WARNING

Rotenone Chronic Toxicity Profile

Study Type	Result
Dog 90-d NOEL 0.4 mg/kg	Decreased growth
Rat and Mouse Teratogenicity	Not teratogenic
Rat 2-Generation Reproduction	Not a reproductive toxin
Rat and Mouse Oncogenicity	Not carcinogenic
Bacteria and Mouse Gene Mutation	Not mutagenic

Summary of CFT Legumine Toxicity

- Oral & inhalation moderately toxic (WARNING)
- Little dermal & eye toxicity or irritation
- Not carcinogenic, teratogenic, or mutagenic
- Parkinson's Disease
  - No causal relationship to rotenone exposure
  - Contradictory laboratory & epidemiological studies
  - Applicators at highest risk of exposure
- Risk = *f [toxicity • exposure]*
  - Cannot control toxicity but can control exposure
  - Control exposure to environment by dosage & frequency restrictions
  - Control exposure to applicator by PPE restrictions
- Rotenone in CFT Legumine less toxic than pure rotenone

CFT Legumine Hazard Summary

- May be fatal if inhaled
- May be fatal if swallowed
- Causes moderate eye irritation
- Harmful if adsorbed through skin
- Avoid:
  - Getting in eyes or on skin or clothing
  - Breathing vapors or spray mist

Section II
Pesticide Safety & PPE

- Working safely with pesticides
  - Read & follow label directions
  - Be especially careful of undiluted pesticides
  - Wear required correct PPE
- CFT Legumine Label
  - Signal word – Warning (Category II)
  - Precautionary statements
  - First aid instructions for exposure
  - Use instructions (rate, mixing & loading)

Major Routes of Pesticide Exposure

- Inhalation – breathing product mist, dust & volatile vapors
- Ingestion – swallowing treated water or product
- Absorption – treated water or product through the skin
- Eyes – splashing of treated water or product

CFT Legumine

Fish Toxicant

SHAKE WELL BEFORE USING

RESTRICTED USE PESTICIDE

Due to acute inhalation, acute oral and aquatic toxicity. For retail sale to, and use only by, Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification.

THE APPLICATOR IS RESPONSIBLE FOR CONFORMING TO THE LABEL. IMPORTANT GUIDANCE ON THE SAFE AND EFFECTIVE USE OF THIS PRODUCT IS PROVIDED IN THE *ROTENONE SOP MANUAL*, AVAILABLE FROM THE REGISTRANT OR THE AMERICAN FISHERIES SOCIETY AT *www.fisheries.org/units/rotenone*

FOR CONTROL OF: Fish in Lakes, Ponds, Reservoirs and Streams

SPECIMEN LABEL

ACTIVE INGREDIENTS:

Rotenone	5% w/w
Cube Resins other than rotenone	5%
OTHER INGREDIENTS*	90%
TOTAL	100%

*Contains Petroleum Distillates

KEEP OUT OF REACH OF CHILDREN

WARNING

See Additional First Aid, Precautionary Statements and Directions for Use including Storage and Disposal Instructions

EPA Reg.No. 89459-48

EPA Est. No. Ⓐ 44616-MO-1 Ⓑ 44616-MO-2

PRECAUTIONARY STATEMENTS – HAZARDS TO HUMANS AND DOMESTIC ANIMALS – WARNING

May be fatal if inhaled. Do not breath the vapors or spray mists. May be fatal if swallowed. Causes moderate eye irritation. Harmful if absorbed through skin. Do not get in eyes or on skin or clothing.

FIRST AID

Have product container or label with you when obtaining treatment advice.

If inhaled	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. • Call a poison control center or doctor for further treatment advice.
If swallowed	• Call a poison control center or doctor immediately for treatment advice. • Do not give any liquid to the person. • Do not induce vomiting unless told to do so by the poison control center or doctor. • Do not give anything by mouth to an unconscious person.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center or doctor for treatment advice.

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may contact 1-800-248-7763 for emergency medical treatment information. You may also contact the National Pesticide Telecommunication Network at 1-800-858-7378 for information including health concerns, medical emergencies or pesticide incidents.

NOTE TO PHYSICIAN: Contains petroleum distillate. Vomiting may cause aspiration pneumonia. Symptoms of exposure include numbness, lethargy and incoordination. Decontamination, symptomatic and supportive treatment is recommended.

Personal Protective Equipment (PPE)

Some materials that are chemical resistant to this product are Barrier Laminate, Nitrile Rubber, Neoprene Rubber or Viton. If you want more options, follow the instructions for Category E on EPA chemical-resistance category selection chart.

All mixers, loaders, applicators, and other handlers (except pilots) must wear at a minimum, the following PPE: (1) coveralls, over long-sleeved shirt and long pants; (2) chemical-resistant gloves; (3) chemical-resistant footwear plus socks; (4) protective eyewear; and (5) a dust/mist respirator.

In addition, mixers, loaders, and others exposed to the concentrate, through cleaning equipment or spills must wear a chemical-resistant apron.

Exception: waterproof waders may be worn in place of coveralls, chemical-resistant apron and chemical-resistant footwear.

See Engineering Controls for additional requirements and exceptions.

User Safety Requirements

Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry. Discard clothing and other absorbent materials that have been drenched or heavily contaminated with this product's concentrate; do not reuse them. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, using tobacco or using the toilet. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals.

Engineering Controls for Mixing/Loading/Applying Liquid Formulations Packaged in Containers > 5 Gallons

Mixers/loaders/applicators must either:

(1) Use a closed system that meets the requirements listed in Worker Protection Standard (WPS) for dermal protection of agricultural pesticides [40 CFR 170.240(d)(4)], or

(2) Use the Semi-Closed Probe Mixing/Loading/Applicator System described below.

Remove plug from bung of drum containing this product only when drum is sitting on the ground or on a secure level platform, with the drum pointed up. Do not pour this product from its drum.

Transfer product from the drum of the mixing tank by use of a suction hose connected to one end of the suction pump on the mixing tank and connected at the other end to a probe/dip tube. Remove the plug from the bung of the drum and insert the probe/dip tube into the bung of the drum until the foam ring/gasket fits snugly around the bung opening to minimize leakage of liquid rotenone. The probe/dip tube should be specifically sized to insure a snug fit into the bung which incorporates an anti-drip flange to remove excess liquid rotenone when the probe/dip tube is removed. In addition, the foam ring/gasket on the probe/dip tube insures a snug fit to minimize leakage of liquid rotenone. Do not handle the probe/dip tube in a manner that allows dripping or splattering of the product onto yourself or any other person. Do not touch the portion of the probe/dip tube that has been in contact with this product until the probe has been triple rinsed with water. See Rotenone SOP Manual (SOP 8) for further information on the operation of the Semi-Closed Probe system.

If the entire product is removed from the drum, then triple rinse the probe while it remains inside of the drum if possible. If not, remove the aspirator probe and triple rinse it and all parts of the aspirator in site water. If an unrinsed probe must be removed from the drum, triple rinse it and all parts of the aspirator in treated site water. The anti-drip flange must be designed to remove excess rotenone product from the probe as it is extracted from the drum. Take the following steps if the probe must be disconnected from the suction hose before both the probe and the hose have been triple rinsed: (1) equip the probe end of the hose with a shutoff valve; (2) install a dry-brake coupling between the valve and the probe, and then close the shut off valve before disconnecting the probe. See Rotenone SOP Manual (SOP 8) for further information on unrinsed probes.

Mixers/loaders/applicators using all systems must wear PPE as required in the PPE section of this labeling for mixers/loaders. All systems must be capable of removing the pesticide from the shipping container and transferring it into mixing tanks and/or application equipment. At any disconnect point, the system must be equipped with a dry disconnect or dry-couple shutoff device to minimize drips.

Transferring (Mixing/Loading) Liquid Formulations

Mixers and loaders must transfer product from original to mixing tank or secondary container using a measuring device, inside a plastic-lined bermed area or other secondary confinement area capable of recovering spilled product. Wash plastic liner or other secondary confinement area and dispose of into treated site water. Do not handle this product in a manner that drips or splatters the product onto yourself or any other person. See Rotenone SOP Manual (SOP 10) for further guidance.

Product Containers ≤ 5 Gallons – Transfer product from original container into measuring device, within secondary confinement area, by pouring or using pump or pipette-type device. See Rotenone SOP Manual (SOP 10) for further guidance.

Product Containers > 5 Gallons – Do not pour rotenone concentrate from containers > 5 gallons. Transfer product from original container into measuring device, within secondary confinement area, using hand or electric drum pump. See Rotenone SOP Manual (SOP 10) for further guidance.

Engineering Controls for Applying Liquid Formulations

Applications using a boom or other mechanized equipment must release this product below the water surface. Applications made with aircraft, backpack sprayer, drip can, or handheld or hand-directed nozzle may release this product above the water surface.

Engineering Controls for Aerial Applications

Open cockpits are prohibited. Pilots must use a cockpit that has a nonporous barrier that totally surrounds the cockpit occupants and prevents contact with pesticides outside the enclosed area. Pilots in enclosed cockpits may wear a long-sleeved shirt, long pants, shoes, and socks instead of the PPE required for applicators in the PPE section of this labeling.

Engineering Controls for Boat Applications

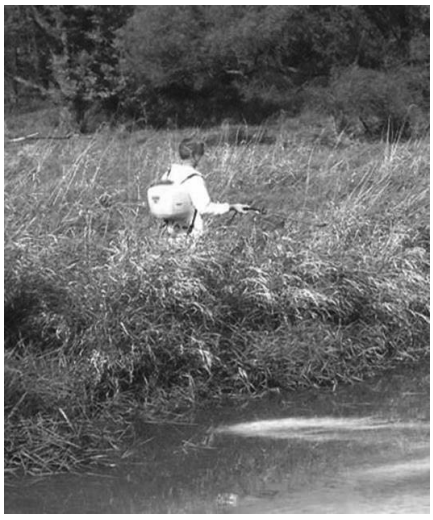
When boat pilots or others on the application boat are located within an enclosed area that has a nonporous barrier that totally surrounds the occupants and prevents contact with pesticides outside the enclosed area; they: (1) may wear long-sleeved shirt, long pants, shoes, and socks, instead of the PPE required for applicators in the PPE section of this labeling; (2) must be provided and have immediately available in the use of an emergency when they must exit the enclosed area while the application is taking place, the PPE required for applicators of the PPE section of this labeling; (3) must take off any PPE that is worn while outside the enclosed area before reentering the enclosed area; and (4) store all used PPE in a chemical-resistant container, such as a plastic bag, to prevent contamination of the enclosed area.

Wearing Right Kind of Protection

- Goggles
  - Required when mixing, loading & applying
  - Safety glasses, face shield or full-face mask
- Chemical-resistant gloves
  - Required when mixing, loading & applying
  - Never fabric-lined
- Coveralls or Tyvek suit (potential heat stress)
  - Required with Class 1 or II pesticides
  - Chemically repellent
  - New suit each day
  - Heat stress reduction (slits in armpits & inseams for ventilation)
- Dust-mist respirator (e.g., TC-84-2561) when spraying
- Chemical-resistant footwear or waders

Sharp-Dressed Applicator

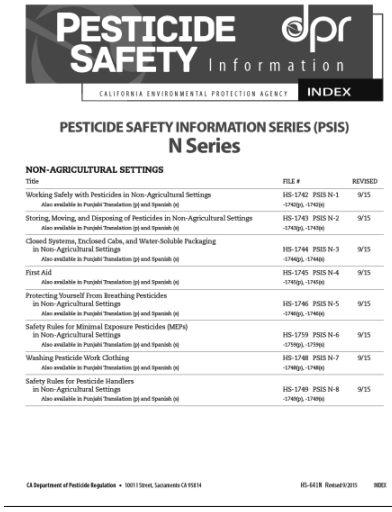
(Tyvek suit, gloves, waders, goggles & respirator)



CFT Legumine on Hands

- Keeping CFT Legumine off of hands
- Hands transport pesticides
  - Eyes when rubbing
  - Mouth when touching food
- Frequently wash hands
  - Eating
  - Drinking
  - Smoking

Pesticide Safety Information Series
http://www.cdpr.ca.gov/docs/whs/psisenglish.htm



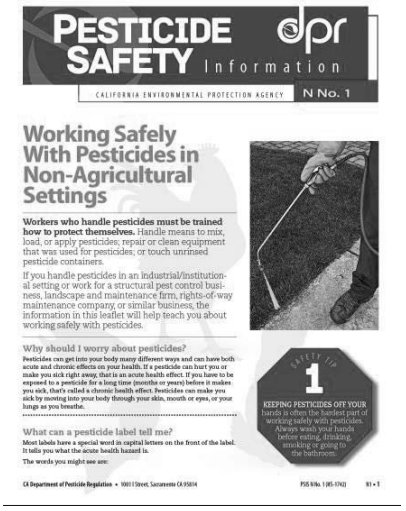
PESTICIDE SAFETY Information
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY INDEX

PESTICIDE SAFETY INFORMATION SERIES (PSIS)
N Series

NON-AGRICULTURAL SETTINGS

Title	FILE #	REVISED
Working Safely with Pesticides in Non-Agricultural Settings Also available in Punjabi Translation (p) and Spanish (s)	HS-1742 PSIS N-1 -1743(p), -1743(s)	9/15
Storing, Moving, and Disposing of Pesticides in Non-Agricultural Settings Also available in Punjabi Translation (p) and Spanish (s)	HS-1743 PSIS N-2 -1743(p), -1743(s)	9/15
Closed Systems, Enclosed Cabs, and Water-Soluble Packaging in Non-Agricultural Settings Also available in Punjabi Translation (p) and Spanish (s)	HS-1744 PSIS N-3 -1744(p), -1744(s)	9/15
First Aid Also available in Punjabi Translation (p) and Spanish (s)	HS-1745 PSIS N-4 -1745(p), -1745(s)	9/15
Protecting Yourself From Breathing Pesticides in Non-Agricultural Settings Also available in Punjabi Translation (p) and Spanish (s)	HS-1746 PSIS N-5 -1746(p), -1746(s)	9/15
Safety Rules for Minimal Exposure Pesticides (MEPs) in Non-Agricultural Settings Also available in Punjabi Translation (p) and Spanish (s)	HS-1759 PSIS N-6 -1759(p), -1759(s)	9/15
Washing Pesticide Work Clothing Also available in Punjabi Translation (p) and Spanish (s)	HS-1748 PSIS N-7 -1748(p), -1748(s)	9/15
Safety Rules for Pesticide Handlers in Non-Agricultural Settings Also available in Punjabi Translation (p) and Spanish (s)	HS-1749 PSIS N-8 -1749(p), -1749(s)	9/15

CA Department of Pesticide Regulation • 1001 I Street, Sacramento CA 95814 HS-6418 Revised 9/2015 INDEX



PESTICIDE SAFETY Information
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY N No. 1

Working Safely With Pesticides in Non-Agricultural Settings

Workers who handle pesticides must be trained how to protect themselves. Handle means to mix, load, or apply pesticides; repair or clean equipment that was used for pesticides; or touch unrinsed pesticide containers.

If you handle pesticides in an industrial/institutional setting or work for a structural pest control business, landscape and maintenance firm, rights-of-way maintenance company, or similar business, the information in this leaflet will help teach you about working safely with pesticides.

Why should I worry about pesticides?

Pesticides can get into your body many different ways and can have both acute and chronic effects on your health. If a pesticide can hurt you or make you sick right away, that is an acute health effect. If you have to be exposed to a pesticide for a long time (months or years) before it makes you sick, that's called a chronic health effect. Pesticides can make you sick by moving into your body through your skin, mouth or eyes, or your lungs as you breathe.

What can a pesticide label tell me?

Most labels have a special word in capital letters on the front of the label. It tells you what the acute health hazard is.

The words you might see are:

SAFETY TIP 1
KEEPING PESTICIDES OFF YOUR hands is often the hardest part of working safely with pesticides. Always wash your hands before eating, drinking, smoking or going to the bathroom.

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Pesticide Safety Information Series
http://www.cdpr.ca.gov/docs/whs/psisenglish.htm

PESTICIDE SAFETY Information
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY N No. 4

First Aid — How do I get ready for an emergency?

In case of an emergency, your employer must make arrangements ahead of time to provide you with emergency medical care if you handle pesticides. You should know the name of this clinic or hospital and where it is. If you don't know, ask your employer before an emergency happens. Never let sick or hurt people drive themselves to a doctor. They could have an accident on the road.

What should I do if someone collapses while they are using pesticides?

- Get the person away from the pesticides if you can without hurting yourself. Remember the sick person might have pesticides on them that could get on you.
- Get help RIGHT AWAY. If you have a phone, call 911.
- Try to stop pesticides from getting in or on the person's body. You can find out how later in this handout.
- If the person is not breathing, give CPR (cardiopulmonary resuscitation) if you know how. The emergency responders will take over when they arrive.

REMEMBER: Tell the emergency responders about the pesticide(s). Also, remember that pesticides may not be the problem. It could, for instance, be a heart attack.

What should I do if someone swallows a pesticide?

- Get help RIGHT AWAY. If you have a phone, call 911, or the free phone number for California Poison Control Center, 1-800-222-1222.
- If people are sleepy or unconscious from poisoning and you don't have a phone, TAKE THEM TO A DOCTOR OR HOSPITAL RIGHT AWAY.

SAFETY TIP 4
In case of an emergency CALL 911

READ THE LABEL FIRST

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PESTICIDE SAFETY Information
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY N No. 8

Safety Rules for Pesticide Handlers in Non-Agricultural Settings

The pesticide label, your training, and this leaflet, tell you about pesticide dangers at work.
Your employer must teach you how to use pesticides safely and how to protect yourself when you use them. Pesticides are chemicals that are used to control unwanted insects, weeds, and plant diseases.

EMPLOYERS: This is the hazard communication leaflet for pesticide handlers. Fill in the blank lines in this leaflet and display this handout at the employee's worksite.

Emergency medical care

Your employer must make plans for emergency medical care before you start working with pesticides. If you think that pesticides made you sick or hurt you at work, tell your employer. They must make sure that you are taken to a doctor right away. DO NOT TAKE YOURSELF.

Emergency medical care is available at (address and telephone number):

REMEMBER: You do not have to pay for medical care if you get sick or hurt from pesticides at work.

If you think pesticides have made you sick at work, your employer must make sure that you are taken to the doctor IMMEDIATELY.

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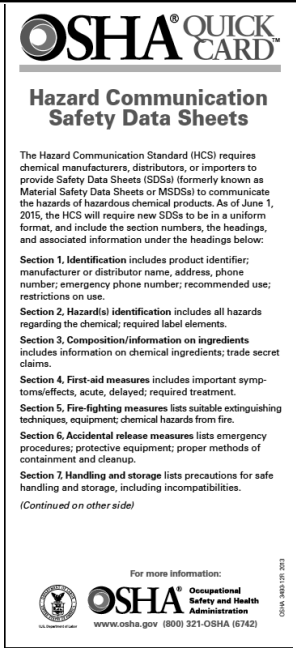


OSHA® QUICK CARD™

Hazard Communication Safety Data Sheets

The Hazard Communication Standard (HCS) requires chemical manufacturers, distributors, or importers to provide Safety Data Sheets (SDSs) (formerly known as Material Safety Data Sheets or MSDSs) to communicate the hazards of hazardous chemical products. As of June 1, 2015, the HCS will require new SDSs to be in a uniform format, and include the section numbers, the headings, and associated information under the headings below:

Section 1, Identification includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.

Section 2, Hazard(s) identification includes all hazards regarding the chemical; required label elements.

Section 3, Composition/information on ingredients includes information on chemical ingredients; trade secret claims.

Section 4, First-aid measures includes important symptoms/effects, acute, delayed; required treatment.

Section 5, Fire-fighting measures lists suitable extinguishing techniques, equipment; chemical hazards from fire.

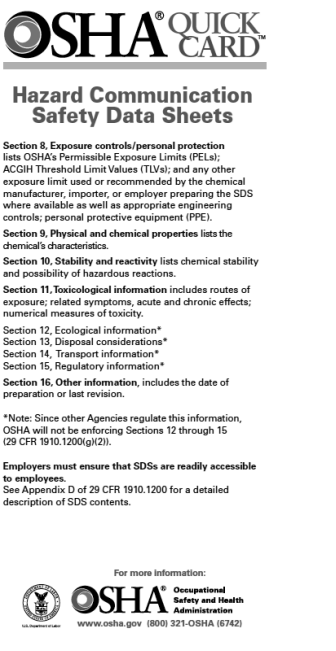
Section 6, Accidental release measures lists emergency procedures; protective equipment; proper methods of containment and cleanup.

Section 7, Handling and storage lists precautions for safe handling and storage, including incompatibilities.

(Continued on other side)

For more information:
OSHA® Occupational Safety and Health Administration
www.osha.gov (800) 321-OSHA (6742)

OSHA 3493-12R 2013



OSHA® QUICK CARD™

Hazard Communication Safety Data Sheets

Section 8, Exposure controls/personal protection lists OSHA's Permissible Exposure Limits (PELs); ACGIH Threshold Limit Values (TLVs); and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the SDS where available as well as appropriate engineering controls; personal protective equipment (PPE).

Section 9, Physical and chemical properties lists the chemical's characteristics.

Section 10, Stability and reactivity lists chemical stability and possibility of hazardous reactions.

Section 11, Toxicological information includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.

Section 12, Ecological information*
Section 13, Disposal considerations*
Section 14, Transport information*
Section 15, Regulatory information*

Section 16, Other information, includes the date of preparation or last revision.

*Note: Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15 (29 CFR 1910.1200(g)(2)).

Employers must ensure that SDSs are readily accessible to employees.
See Appendix D of 29 CFR 1910.1200 for a detailed description of SDS contents.

For more information:
OSHA® Occupational Safety and Health Administration
www.osha.gov (800) 321-OSHA (6742)

CFT Legumine SDS

Safety Data Sheet

CENTRAL Garden & Pet

Section 1: Identification

Product identifier

Product Name - Prentox CFT Legumine Fish Toxicant

Synonyms - 100209000; 100209001; EPA Reg. No.: 89459-46

Product Description - Orange viscous liquid.

Relevant identified uses of the substance or mixture and uses advised against

Recommended use - Piscicide.

Restrictions on use -

KEEP OUT OF THE REACH OF CHILDREN. Avoid contact with eyes, skin and clothing. Do not use or store near heat or open flame. Avoid release to the environment. Use in well ventilated area. Avoid inhalation of vapors or fumes. For use by certified applicators or persons under their direct supervisionand only for those uses covered by the Certified Applicator's certification.

Details of the supplier of the safety data sheet

Manufacturer - Central Garden & Pet Company
1501 E. Woodfield Road, Suite 200W
Schaumburg, IL 60173
United States

www.central.com

Emergency telephone number

Manufacturer (Transportation) - 1-800-424-9300 - CHEMTREC

Manufacturer (Transportation) - 1-703-527-3887 - Chemtrec - Outside US collect calls accepted

Manufacturer - 1-800-248-7763

Section 2: Hazard Identification

United States (US)

According to: OSHA 29 CFR 1910.1200 HCS

Classification of the substance or mixture

OSHA HCS 2012 - Eye Irritation 2A
Flammable Liquids 4
Skin Irritation 2
Acute Toxicity Oral 4
Acute Toxicity Inhalation 2
Reproductive Toxicity 1B
Specific Target Organ Toxicity Single Exposure 3: Narcotic Effects

Label elements

OSHA HCS 2012

DANGER

Hazard statements - Causes serious eye irritation
Causes skin irritation
Combustible liquid
Fatal if inhaled.
Harmful if swallowed
May damage fertility or the unborn child.
May cause drowsiness or dizziness

Precautionary statements

Prevention - Wash thoroughly after handling.
Wear protective gloves/protective clothing/eye protection/face protection.
Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
Keep away from heat, sparks, open flames and/or hot surfaces. - No smoking.
Do not eat, drink or smoke when using this product.
Use only outdoors or in a well-ventilated area.
Do not breathe dust, fume, gas, mist, vapours and/or spray.
In case of inadequate ventilation wear respiratory protection.
Keep away from flames and hot surfaces. - No smoking.
Wear respiratory protection.

Response - IF ON SKIN: Wash with plenty of soap and water.
Specific treatment, see supplemental first aid information.
If skin irritation occurs: Get medical advice/attention.
Take off contaminated clothing and wash before reuse.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
Do NOT induce vomiting.
If eye irritation persists: Get medical advice/attention.
In case of fire: Use appropriate media Water fog, foam, dry chemical or carbon dioxide (CO2), for extinction.
Immediately call a POISON CENTER or doctor/physician.
IF exposed or concerned: Get medical advice/attention.
IF INHALED: Remove person to fresh air and keep comfortable for breathing. Call a poison control center or doctor if you feel unwell.

Storage/Disposal - Dispose of content and/or container in accordance with local, regional, national, and/or international regulations.
Store in a well-ventilated place. Keep cool.
Store locked up.
Keep container tightly closed.

Other hazards

OSHA HCS 2012 -

This product is extremely toxic to fish. Under United States Regulations (29 CFR 1910.1200 - Hazard Communication Standard), this product is considered hazardous.

Section 3 - Composition/Information on Ingredients

Substances

Section III

Environmental Concerns

- Rotenone toxic to fish – fish kills expected
- Cleaning of equipment & disposal of wash waters in treatment area only
- Rotenone not toxic to wildlife @ use rate
- Low BCF & vapor pressure & quickly degrades
- Hydrolysis half-lives in days
- Photolysis half-lives in hours
- Abiotic & biotic degradation

Section IV
Rights & Access to Label & SDS

- CFT Legumine Hazard Communication Book
  - CFT Legumine label
  - CFT Legumine SDS
  - Pesticide Safety Information Series
  - AFS Rotenone SOP Manual
    - Chapter 1 summary of Public Health studies
    - Chapter 1 summary of Environmental Fate studies
    - SOPs 2, 3 & 4
- Agency's Hazard Communication Program
  - Agency's pesticide use records
  - Pesticide Safety Information Series
  - Pesticide SDSs and labels
  - Agency's training records

SOP 3.0 - Appendix A

Rotenone Product _____[1] Safety Training Record

This is to certify that _____has received _____hours of rotenone safety training.

Employee Signature_____ Employee Title_____

Employee Work Location_____Trainer_____Date_____

Training Requirements:

Safety Procedures: personal protective equipment, engineering controls, and equipment. Heat-related illness†
Pesticide Labels: signal words, precautionary statements, first aid instructions, mixing and application instructions†
Pesticide Handling Procedures: container handlings, mixing and application equipment, triple rinse containers†
First Aid and Decontamination: for eyes and skin and location of first aid supplies†
Emergency Procedures: the procedures for handling non-routine tasks or emergency situations such as spills or fire†
Common Symptoms of Overexposure: common symptoms of pesticide poisoning and ways poisoning can occur†
Exposure Hazards: including both acute and chronic effects†
Environmental Concerns: such as drift, runoff and wildlife hazards†
Laws and Regulations: applicable laws and regulations, MSDS, Pesticide Safety Information Series, label requirements†
Employee Rights: receive information on pesticides they may be exposed to, rights against discharge or other discrimination due to exercise of these rights†
Location of Documents: Hazard Communication Program plans, pesticide use records, Pesticide Safety Information Series leaflets, MSDS and training records†

[1] Insert the specific Brand Name of the rotenone product.

Rotenone Storage, Transportation, and Spill Containment
SOP: 4.1

PURPOSE:

1. Mitigate for environmental contamination resulting from rotenone spillage during storage and transportation
2. Provide a protocol for safe and effective storage, transportation, and spill prevention and containment

PROCEDURE:

I. Storage

A. Original and Service Containers

Rotenone is stored in original containers or in approved service containers that are in a dry place that is inaccessible to children and pets. Service containers can be any secure and operational storage container except those of a type commonly used for food, drink or household products. Service container labeling must be kept intact throughout the use of the container and must include:

- The name and address of the person or entity responsible for the container
- The identity of the pesticide in the container
- The signal word that appears on the label of the original container (i.e., "DANGER," "WARNING," or "CAUTION")

B. Guidelines for Long-term Storage Facilities

Pesticide storage areas should be in a separate room from office and residential spaces, water supply sources, and food or feed storage areas. Long-term storage of pesticides and pesticide containers should be in a fire-resistant structure with good ventilation and a sealed, concrete floor that slopes toward drainage and secondary containment. Pesticide storage areas should have separate entries if possible. Pesticide storage areas should have security and access control provisions including a locked door and locked windows (or no windows) to prohibit access. If liquid products are to be stored, the storage area should have a containment system capable of containing at least 25% of the stored liquid volume. Typical containment systems include a bermed floor or a sloped floor with a sump. The building temperature should be kept lower than 95°F (35°C) and above pesticide freezing points. All electrical fixtures and appliances in the storage area should be non-sparking units approved for use in facilities storing flammable and combustible liquids, if applicable. Weatherproof signs stating "Danger – Pesticides – Keep Out" or similar warning should be posted on each door and any window. Post the name, address, and phone number of a

contact person at the primary entrance to the storage area. Signs visible from any direction of probable approach shall be posted around all storage areas where containers that hold, or have held, pesticides required to be labeled with the signal words "WARNING" or "DANGER" (Category I or II pesticides) are stored. Each sign shall be of such size that it is readable at a distance of 25 feet (7.6 m) and contains the following text:

"DANGER
POISON/PESTICIDE STORAGE AREA
ALL UNAUTHORIZED PERSONS KEEP OUT
KEEP DOOR LOCKED WHEN NOT IN USE"

The notice shall be repeated in an appropriate language other than English when it may reasonably be anticipated that persons who do not understand the English language will come to the enclosure.

C. Guidelines for Project Site

Acceptable storage enclosures may be a closed vehicle, closed trailer, a building, room, or fenced area with a fence at least six feet high, a foot locker or other container that can be locked, and trucks or trailers that have solid sideracks and secured tailgates at least six feet above ground, ramp, or platform level. Metal containers with screw-type bungs and/or secured and locked valves and sealed five-gallon containers are also acceptable storage enclosures. Because storage requirements may vary, consult your State pesticide regulation office to ensure compliance with local rules.

II. Transportation

A. Federal Regulation

The legal requirements regarding hazardous material transport, required training, placarding and special licenses are contained in Title 49 of the Code of Federal Regulations (49 CFR). The safety data sheets (SDSs) for rotenone formulations state that they are class 6.1 (poisonous materials) and marine pollutants. Depending upon the formulation, a liquid rotenone product may also be classed as a flammable liquid. Due to the considerable environmental risks associated with the transport of rotenone formulations, it is crucial that commercial carriers have the required training and credentials required by 49 CFR.

B. State Exemption

The federal codes regulating transport of hazardous materials exempts state agencies from many of the requirements regarding hazardous materials training, license endorsements, and placarding. However, given the need to protect the public and the environment when transporting hazardous materials, it is recommended that public agencies comply with the federal codes to the fullest extent possible. Commercial hazardous material carriers should be contracted when undertaking large projects if government carriers are not fully trained and not appropriately credentialed.

C. Restrictions

Pesticides shall not be transported in the same compartment with persons, food, or feed. Pesticide containers shall be secured to vehicles during transportation in a manner that will prevent spillage onto the vehicle or off the vehicle. Paper, cardboard, and similar containers shall be covered (i.e., plastic tarp) when necessary to protect them from moisture. Carry shipping papers in your vehicle including emergency response phone numbers and SDSs must be present in the vehicle when transporting rotenone. Prior to transport, the applicator or vehicle driver must ensure that pesticide containers are properly labeled and secured.

D. Government Agency Documentation

It is recommended that federal, state, or local government workers transporting rotenone keep a document in the transportation vehicle stating their compliance with federal Hazardous Materials Regulations (HMR):

In accordance with § 49 CFR 171.1 (d)(5), which states:

(d) *Functions not subject to the requirements of the HMR*.
The following are examples of activities to which the HMR do not apply:

…(5) Transportation of a hazardous material in a motor vehicle, aircraft, or vessel operated by a federal, state or local government employee solely for noncommercial Federal, state, or local government purposes.

[this agency] is exempt from the HMR (§ 49 CFR 171 through 180) as it applies to the Packaging, Pre-transportation, and Transportation functions of hazardous materials.

Please contact the [agency] Safety Office at [telephone or other contact] if there are any concerns regarding this exemption.

III. Spill Prevention and Containment

A. Spill Prevention

Off-site spills may be associated with improper storage or accidents during handling and transport. Generally, all spills must be reported to the state spill response unit and other units as appropriate. Small spills may be contained and the collected material disposed of according to the product label. If these wastes cannot be disposed of by use according to label instructions contact your state pesticide or environmental control agency, or the hazardous waste representative at the nearest EPA Regional Office for guidance.

It is recommended that applicators create a Spill Contingency Plan (Section IV). Spill contingency plans can help avoid or minimize on-site spills. The complexity of the spill contingency plan will depend upon the size and detail of the rotenone treatment. Large projects will require detailed plans that consider project security and avoidance

of catastrophic spills. The spill contingency plan should detail where the material will be stored on site while awaiting application.

B. Spill Containment

The storage of rotenone materials at the project location may be in a location that is graded to allow drainage to the project water body in case of an accidental spill. Containers of rotenone powder and liquid may be set on a plastic barrier, concrete ramp, or other impermeable surface sloped toward the project water body. A small spill of rotenone can then be rinsed into the treated water.

The designated storage area on-site should be bermed and should be large enough to contain all the stored material. This will allow recovery of all the material. The berm may be constructed of straw/hay bales or other suitable material and should be lined with heavy duty plastic fabric. Portable bilge pumps, hoses, buckets, drums, absorbent clay, and absorbent pads and other recovery equipment as well as personal protective equipment should be maintained in an adjacent area readily available in case of a spill. Each person who controls the use of any property or premises that holds, or has held rotenone, is responsible for all containers or equipment on the property. Unless all such containers are under personal control so as to avoid contact by unauthorized persons, make arrangements to (1) provide a person responsible to maintain such control over the containers at all times or (2) store all such containers in a locked enclosure, or in the case of liquid pesticides in a container larger than 55 gallons (208 L) in capacity, the container shall have a locked closure. Either shall be adequate to prevent unauthorized persons from gaining access to any of the material.

C. Spill Management

In the event of a spill, it is extremely important that the spilled material be contained. If a ground spill occurs, immediately control the spill at its source and contain or channelize the spilled material into a containment area with shovels and other hand tools. Once the material is contained or diked into pools, the applicator should attempt to recover the material by using absorbent materials such as clay, soil, sawdust or straw to absorb pooled liquids or collection by pump or sponge. Recovered material can be applied to the treatment area according to label instructions and other local, state, and federal regulations.

IV. Spill Contingency Plan

The Spill Contingency Plan should contain the following information:

- Inventory of materials to be used in the treatment (products, location, and amount)
- Description of storage areas (size, construction details, and security measures)
- Description of staging areas, mixing areas, treatment areas, and deactivation areas
- Precautions—specific to the site, locale, and treatment

- Chain of Command—details the flow of information and responsibility for all facets of the treatment
- Contact information for all downstream water users who would be impacted in the event of a major spill
- Contact information of all entities that must be contacted in the event of a reportable spill. This list is to be provided to all project personnel and should be with them at all times.
- Specific spill containment and recovery procedures
- Indicate mode of communication and all referenced areas on a map

V. Additional Information

University of California, Statewide Integrated Pest Management Program 2000. The Safe and Effective Use of Pesticides, 2nd edition. Agricultural and Natural Resources Publication 3324.

University of Nebraska, Lincoln. Safe Transport, Storage, and Disposal of Pesticides. Extension Publication ED2507. Available: www.ianrpubs.unl.edu/epublic/live/ec2507/build/ec2507.pdf.

University of Nevada, Reno, Cooperative Extension. Safe and Legal Transportation of Pesticides, Special Publication SP-01-09. Available: www.unce.unr.edu/publications/files/ag/2001/sp0109.pdf.

Treatment Rates and Strategies
SOP: 5.1

PURPOSE:

1. Provide strategies for eliminating undertreatment and overtreatment of target species
2. Provide guidance on conducting bioassays and designing treatments using effective pest management techniques
3. Provide strategies for implementing selective treatments and biomanipulation

PROCEDURES FOR A COMPLETE ERADICATION TREATMENT:

I. Coverage of Water Treated Using Labeled Rates

The actual treatment rate and rotenone concentration needed to kill a target species varies widely, depending on the type of water, environmental factors including pH, temperature, depth, turbidity, and organic-loading, and sensitivity of target species. Tables SOP 5.1 (SOP Table 5.2 for metric) and SOP 5.3 (SOP Table 5.4 for metric) are general guides for proper rates and rotenone concentrations for eradication of target species (i.e., complete kills of target species) and provide estimates of expected coverage in either standing or flowing waters. The Certified Applicator (or someone acting under their direct supervision) must conduct bioassays using site water (or water of similar quality) and target species (or surrogate species of similar sensitivity) to refine the treatment rate within the maximum limit allowed (see next section on bioassays). It is recommended that the stock of chemical to be used during the treatment should be the same stock used during the bioassay. Use must be consistent with the label, and treatment concentrations above label maximum of 200 ppb rotenone (4 ppm 5% a.i. formulation) are a violation of federal law under FIFRA.

Rotenone application can be controversial, and it is imperative that certified applicators work to minimize impacts to non-target species and non-target areas as defined by agency project proposals. Certified rotenone applicators have a responsibility to apply the minimum concentration necessary

Table SOP 5.1. Recommended rotenone treatment concentrations and number of acre-feet (AF) of standing water covered by one gallon or pound of rotenone formulation (5% a.i.). Adjust amount of formulation according to the actual rotenone content on Ingredient Statement on label.

Type of Use	Parts per Million (ppm)		AF/Gallon[a]	AF/Pound[b]
	Rotenone Formulation	Rotenone		
Normal	0.5–1.0	0.025–0.05	6.0 to 3.0	0.74 to 0.37
Tolerant Species	1.0–3.0	0.05–0.15	3.0 to 1.0	0.37 to 0.123
Tolerant Species in Organic Ponds	2.0 – 4.0	0.1 – 0.2	1.5 to 0.75	0.185 to 0.093

[a] gallons (5% a.i.) = AF × 0.0066 × ppb rotenone
[b] pounds (5% a.i.) = AF × 0.054 × ppb rotenone

Table SOP 5.2. Recommended rotenone treatment concentrations and number of cubic meters (m^3) standing water covered by one liter or kilogram of rotenone formulation (5% a.i.). Adjust amount of formulation according to the actual rotenone content on Ingredient Statement on label.

Type of Use	Parts per Million (ppm)		m^3/L[a]	mg/kg[b]
	Rotenone Formulation	Rotenone		
Normal	0.5–1.0	0.025–0.05	2000 to 1000	2000 to 1000
Tolerant Species	1.0–3.0	0.05–0.15	1000 to 333	1000 to 333
Tolerant Species in Organic Ponds	2.0–4.0	0.1–0.2	500 to 250	500 to 250

[a] L (5% a.i.) = $m^3 \times 0.00002 \times$ ppb rotenone
[b] kg (5% a.i.) = $m^3 \times 0.00002 \times$ ppb rotenone

Table SOP 5.3. Recommended rotenone treatment concentrations and number of cubic feet per second (ft^3/s) flowing water treated for 4- and 8-h periods with one gallon of rotenone formulation (5% a.i.). Adjust amount of formulation according to the actual rotenone content on Ingredient Statement on label.

Type of Use	Parts per Million (ppm)		ft^3/s/Gallon[a,b] (4-h)	ft^3/s/Gallon[a,b] (8-h)
	Rotenone Formulation	Rotenone		
Normal	0.5–1.0	0.025–0.05	15.5 to 9.3	7.8 to 4.6
Tolerant Species	1.0–3.0	0.05–0.15	9.3 to 3.1	4.6 to 1.6
Tolerant Species in Organic Waters	2.0–4.0	0.1–0.2	4.6 to 2.3	2.3 to 1.2

[a] ml/min rotenone formulation = ft^3/s discharge $\times$ 1.699 $\times$ ppm rotenone formulation
[b] ml/min rotenone formulation = ft^3/s discharge $\times$ 0.034 $\times$ ppb rotenone

Table SOP 5.4. Recommended rotenone treatment concentrations and number of cubic meters per second (m^3/s) flowing water treated for 4- and 8-h periods with one liter of rotenone formulation (5% a.i.). Adjust amount of formulation according to the actual rotenone content on Ingredient Statement on label.

Type of Use	Parts per MIllion (ppm)		$m^3/s/L$[a,b] (4-h)	$m^3/s/L$[a,b] (8-h)
	Rotenone Formulation	Rotenone		
Normal	0.5–1.0	0.025–0.05	0.116 to 0.069	0.058 to 0.034
Tolerant Species	1.0–3.0	0.05–0.15	0.069 to 0.024	0.034 to 0.013
Tolerant Species in Organic Waters	2.0–4.0	0.1–0.2	0.034 to 0.018	0.0180 to 0.008

[a] ml/min rotenone formulation = m^3/s discharge $\times$ 59.99 $\times$ ppm rotenone formulation
[b] ml/min rotenone formulation = m^3/s discharge $\times$ 1.2 $\times$ ppb rotenone

to effectively remove or control target species within the treatment area, to prevent over-application and unnecessary impacts to non-target species, and to prevent movement of the chemical outside the treatment area. Continued public support for rotenone treatments depends on proper project planning and execution.

II. Using Bioassay to Determine Site-Specific Treatment Rate

Determine treatment rate, within maximum limits allowed (Tables SOP 5.1 through SOP 5.4), by conducting a bioassay with the target species (or surrogate species of similar sensitivity) in the site water (or water quality equivalent i.e., pH, temperature, turbidity) using the stock solution that will be used during the treatment. The affirmation of potency can be conducted in the laboratory under controlled conditions or in the field immediately prior to treatment. In-situ bioassays can also be used to monitor the efficacy of treatments (see also SOP 14.1).

For example, a bioassay can be completed using 10-gallon (37.9-L) aquaria or 5-gallon (18.9-L) plastic buckets containing 20 or 10 L of water each, respectively. The following rotenone concentrations would be tested: 0.0 (control), 12.5, 25, 50, 100, and 200 ppb. To test these active ingredient concentrations, make a 50 ppm rotenone (1,000 ppm formulation) Rotenone Stock Solution by diluting 1 ml of liquid formulation or 1 g of powder to 1 L of water and mixing thoroughly. Add the amounts indicated in Table SOP 5.5 to 10 or 20 L of test volume.

Add fish and monitor survival at 30, 60, 120, 240, and 480 minutes (0.5, 1, 2, 4, and 8 hours) for stream treatments or at 60, 120, 240, 480, and 1,440 minutes (1, 2, 4, 8, and 24 hours) for lake treatments. Biomass of fish in bioassays should be sufficiently low so that fish survival is not impacted by biomass if untreated. Suggested fish loading levels should not exceed 1g fish per liter of water. Keep test solutions near ambient water temperature with the use of refrigeration or by partially submerging aquaria or buckets in water body if necessary. If the fish loading is exceeded for the size of the container, then use a larger container containing proportionately more water and stock solution. Normally, aeration of test water during the bioassay is not recommended as this may hasten the breakdown on rotenone.

The lowest rotenone concentration that produces 100% mortality of test fish within the treatment duration is the Minimum Effective Dose (MED). For standing water treatments, use mortality estimate for 8 hours exposure as MED. For flowing water, use the expected treatment interval between rotenone application stations. Depending on the pH, turbidity, temperature, sunlight intensity, and depth, treat at a concentration at least twice the MED to ensure complete kills of target fish. Alkaline pH, high temperature, sunlight intensity, turbidity, and dispersion into deep water all affect the breakdown of rotenone. Ensure that maximum rates listed in Tables SOP 5.1 through SOP 5.4 are not exceeded.

Table SOP 5.5. Amount (in ml) of 50 ppm Rotenone Stock Solution (1 ml or 1 g rotenone formulation (5% a.i.) to 1 L water) needed to achieve various concentrations of rotenone in 10 and 20 liters of test solution (control solution receives no Rotenone Stock Solution).

Test Solution	Rotenone 0.0125 ppm	Rotenone 0.025 ppm	Rotenone 0.050 ppm	Rotenone 0.10 ppm	Rotenone 0.20 ppm
10 Liters	2.5	5	10	20	40
20 Liters	5	10	20	40	80

Make sure that measuring devices, aquaria, and other equipment coming in contact with rotenone are cleaned prior to use. Following use, clean all equipment with soap and water and let dry in sunlight prior to reuse. Deactivation with a 1% potassium permanganate solution followed by complete rinsing will assure total elimination of rotenone residues.

Wear required safety gear according to label and SDS when handling rotenone product, dilute rotenone solutions, and potassium permanganate.

Dispose of test fish properly by burying on-site in the ground away from the treated water body, through normal laboratory disposal procedures, or as determined by the Certified Applicator and/or state or applicable wildlife agency.

III. Strategies

Exposing all target fish to sufficient rotenone concentration and duration should result in a complete kill of the target fish species. All habitats capable of supporting target fish within the treatment area should be treated unless there is conclusive evidence that target fish are absent or that the area cannot serve as a safe haven for target fish during the treatment. The consequences of not treating an area in question could lead to incomplete eradication. Physical removal techniques including netting, electrofishing, explosives, and traps all have efficiency biases, and removal of target species can be difficult to achieve with these techniques. Failure to sample target species after treatments is not always conclusive evidence of absence of target fish.

For treatment of streams, habitat includes headwater lakes and all tributaries, seeps and springs that are or may be hydrologically connected to the area scheduled for eradication of target fish. Avoid the flow of untreated water into the treatment area during the treatment; ideally the entire area should concurrently contain lethal levels of rotenone. Normally, place drip stations every one to two hours travel time (or as determined by bioassay) apart on flowing reaches (see SOP 11.1 “Placement of Application Sites”) and spray seeps, backwater areas and springs with dilute rotenone (see SOP 12.1) or treat with rotenone aftermarket mixtures (see SOP 13.1).

For treatment of lakes, habitat includes the entire water body and upstream tributaries. Normally, treat an entire lake within 48 hours to insure that rotenone does not degrade during application. Dispersion of rotenone horizontally and vertically in lakes is required for complete fish kills. Impediments to dispersion of rotenone include backwater and weedy areas that receive little or no water movement, and deep lakes where there is little water exchange through a thermocline. Spraying backwater and weedy areas with dilute rotenone, and pumping rotenone to depth may be required to get it through the thermocline. Identify springs and seeps that may provide sanctuary to target species and treat with liquid rotenone or rotenone aftermarket mixtures (see SOP 13.1). Generally, one application of rotenone is sufficient for complete removal of target species from a lake or pond.

Complex habitats (e.g., seeps, springs, backwaters, and weedy areas) increase the potential that rotenone will not reach lethal concentrations in all stream locations with the result that some fish may not be killed. For this reason, it is recommended that multiple treatments be employed. The treatments should be adequately spaced in time to allow eggs time to hatch and develop so they become vulnerable to a second treatment. Spacing treatments also allows time for physical conditions (e.g., vegetation, flows, and water levels) to change which will change exposure conditions for the fish. Multiple applications of rotenone over several years may be required for complete removal of target species from a stream or river.

IV. Sentinel Fish to Monitor Effectiveness of Rotenone

Normally, place cages containing fish upstream of all drip cans in streams and at various locations and depths in lakes to monitor the effectiveness of the treatment. Target those areas where poor water movement or premature breakdown of rotenone is expected such as waterfalls in streams and weedy areas of lakes. Careful monitoring of sentinel fish during or following the application is used to adjust treatment rate and application site and method. The species of sentinel fish should be carefully selected to ensure that treatment goals are not compromised should fish escape from containment vessels.

V. Strategic Considerations for Complete Eradication of Target Fish Species

- Treat all known habitat within project area capable of supporting fish
- Avoid undertreatment and escapement
- Avoid overtreatment, excessive rotenone residues, and inadequate deactivation
- Use liquid rotenone in streams and lakes
- Use powdered rotenone only in lakes, or as described in SOP 13.1
- Use accurate and up-to-date volume, temperature, depth, and surface area measurements of lakes
- Use accurate and up-to-date flow, temperature, velocity, and length of streams
- Identify extent of fish distribution and habitat use
- Identify all barriers to fish and water movement
- Identify all types and densities of aquatic vegetation
- Identify all inlets/outlets and seeps/springs
- Use block nets where appropriate to prevent target fish escapement

PROCEDURES FOR SELECTIVE TREATMENTS AND BIOMANIPULATION:

Rotenone treatments can be utilized for the selective eradication of target species or for the biomanipulation (biomass reduction) of certain fisheries. Tolerance to rotenone varies among and within fish species (see Table 1.3) and this difference can be exploited by managers. Eradication efforts are most often successful when there is considerable separation of rotenone tolerance between target and non-target species, whereas biomanipulation efforts are aimed at the reduction of target species abundance, but not elimination.

Only liquid formulations of rotenone should be used in selective treatments, and treatments should be conducted at relatively cool temperatures (<55°F) to retard rotenone degradation and improve contact time with target species. Note that the use of standard petroleum-based formulations is recommended to improve mixing during cool water applications. Rotenone concentrations for selective treatments are typically 3–10% of concentrations used for complete fish removal (see Table SOP 5.6). The key to success is the methodical application of rotenone throughout the waterbody at a concentration appropriate for the most tolerant target species. Increased application effort is required to ensure even dispersal of rotenone both horizontally and vertically in the waterbody. Applicators should endeavor to achieve as complete an application to the entire water column as possible.

VI. Lake Mapping

Determine treatment rate, within maximum limits allowed (Tables SOP 5.1 through SOP 5.4), by conducting a bioassay with the target species (or surrogate species of similar sensitivity) in the site

Table SOP 5.6. Typical treatment concentrations and number of acre-feet (AF) standing water covered by one gallon of rotenone formulation (5% a.i.) for typical and selective treatments. Adjust amount of formulation according to the actual rotenone content per third party assay for selective treatments.

Type of Use	Parts per Million (ppm)		Gallon/AF[a,b]	AF/Gallon
	Rotenone Formulation	Rotenone		
Normal	0.5–1.0	0.025–0.05	0.17–0.33	6.0 to 3.0
Tolerant Species	1.0–3.0	0.05–0.15	0.33–0.98	3.0 to 1.0
Tolerant Species in Organic Ponds	2.0 – 4.0	0.1 – 0.2	0.65–1.30	1.5 to 0.75
Selective Treatment	0.06–0.03	0.003–0.015	0.0198–0.099	50.5 to 10.1

[a] gallons (5% a.i.) = AF × 0.0066 × ppb rotenone
[b] pounds (5% a.i.) = AF × 0.054 × ppb rotenone

water (or water quality equivalent i.e., pH, temperature, turbidity) using the stock solution that will be used during the treatment. The affirmation of potency can be conducted in the laboratory under controlled conditions or in the field immediately prior to treatment. In-situ bioassays can also be used to monitor the efficacy of treatments (see also SOP 14.1).

A high degree of accuracy in lake volume calculation is required for selective treatments as the margin for error can be narrow. Excessive rotenone concentration will result in high non-target species mortality, whereas insufficient treatment may fail to affect the target population to the desired degree. Bathymetric measurements of lake basins should be collected using hydroacoustic sonar equipment capable of collecting georeferenced depth data. Post-processing survey data can be accomplished using a software package capable of interpolating lake volume. The lake should be subdivided into zones, each corresponding with 10–40 surface acres for individual treatment. In addition, zones should be subdivided vertically into shallow and deep zones. When depth exceeds 20 feet, at least two vertical strata should be identified. Applicators may identify as many vertical strata as desired to improve the level of application accuracy.

VII. Bioassay

The level of differential rotenone tolerance is relatively small (slightly over an order of magnitude) across fish species; therefore, the actual rotenone concentration of the formulation used in selective treatments should be analytically confirmed. The actual concentration of rotenone can vary plus/minus 20% from the labeled 5% a.i. (Flammang 2014). Concentrations can vary among manufacturers, lots, dates of manufacture, and storage time. Also, rotenone concentration has been observed to vary over time in the original container, especially once opened. This variability may have negative effects on the success of selective treatments by causing non-target species mortality (due to higher-than-expected concentration) or failure to affect the target species to the degree wanted (due to lower-than-expected concentration). Applicators should have the stock rotenone that will be used during a selective treatment analyzed by a laboratory prior to use (See SOP 16.1 for more information on analytical chemistry). Make sure the undiluted formulation is well mixed before sampling for chemical analysis (SOP 16.1) and toxicity testing (SOP 5.1). In addition to the analytical confirmation of rotenone content, it is equally important to conduct bioassays with the target species life-cycle stage targeted using the site water (see this SOP "Using bioassay to determine site-specific treatment rate").

VIII. Planning Steps

Planning procedures (SOP 2.1) are similar for both complete fish removal and selective treatments. However, in many cases of selective treatment, the plan may be condensed and specific steps may be abbreviated. Nonetheless, a clear statement of need must be prepared and delivered to all partners and user groups. One of the initial points of discussion is to identify the problem and determine if selective treatment is an option. Partners must be informed of important biological, ecological, and water quality impacts of the injurious species. The presence of quality low-tolerance game fishes would likely preclude the immediate use of selective treatments, unless the natural resource agency and public are prepared for the loss of these fisheries. Alternatively, the selective treatment might be delayed to a time when game fish populations have declined naturally in the face of the cessation of maintenance stockings.

IX. Target Species

The toxicity of rotenone to fishes has been shown to be both size- and species-specific. Table 1.3 provides generalized rotenone susceptibility information gathered by multiple authors on various fish species. Species that are most effectively removed by selective treatment are those that exhibit relatively low tolerance to rotenone. For instance, Yellow Bass *Morone mississippiensis* and Gizzard Shad *Dorosoma cepedianum* have been selectively eradicated from specific systems with minimal impacts to important non-target centrarchid fisheries. Selective treatments are more often successful when there is relatively greater separation in tolerance between target and non-target species. For instance, applicators would have little success in eliminating Gizzard Shad without negative impacts to Walleye *Sander vitreus* populations. However, the removal of Northern Pike *Esox lucius* may be possible with little negative impact on Crappie *Pomoxis* spp. In addition to selective eradication, fisheries managers may wish to reduce biomass of certain species without complete eradication. For instance, biomanipulation efforts may be utilized for the population reduction of high-density Bluegill *Lepomis macrochirus*, which has been shown to result in improved growth and size structure in treated populations.

Suggested treatment concentrations for some commonly treated species are noted in Table SOP 5.7. Grass Carp *Ctenopharyngodon idella* may be targeted using special techniques. While the species is

Table SOP 5.7. Suggested target concentrations of rotenone and rotenone formulation (5% a.i.) needed for selective rotenone treatments of some target species.

Suggested Target	Special Notes	Rotenone Formulation (ppm)	Rotenone (ppb)
Walleye removal		0.06–0.10	3.0–5.0
Gizzard Shad removal		0.10–0.16	5.0–8.0
Yellow Bass removal		0.12–0.16	6.0–8.0
Bluegill population structure biomanipulation	Multiple treatments may be required	0.16–0.18	8.0– 9.0
Grass Carp reduction	Capture of stressed fish may be required	0.14–0.20	7.0–10.0

relatively tolerant of low-concentration rotenone, the fish often exhibit stressed behavior and appear lethargic at the water surface for a period of hours following application. The use of mechanical removal of stressed fish has been successfully employed to reduce overall density before these fish recover. Use bioassay techniques in SOP 5.1 and SOP 14.1 to refine the rotenone concentration needed for targeted species removal and reduction to ensure the target concentration is within acceptable limits of mortality of other species.

X. Application

Typically spray application is not required for selective treatments. Application may be made with a semi-closed system (SOP 8.1) or with a modified pumping system that applies chemical from a mixing tank under the surface of the water (see Figure SOP 11.4) from a boat. The terminal end of the hose may be attached directly to the lower unit of the boat motor so that the rotenone solution is applied directly in front of the prop wash (see Figure SOP 11.3). Treatments usually are performed in the late fall or spring when water temperatures are <55°F (where possible). Applications can be made as long as the lake remains ice-free; rotenone is applied over a 4–5 h time period for each zone.

All zones should be applied concurrently. Total rotenone need for each zone should be divided by the anticipated number of tank fills to occur over the 4–5 hour application period. Rotenone concentration within the mixing tank will not exceed 10%, and the solution should be well-mixed prior to application. Table SOP 5.8 demonstrates the parsing of rotenone by zone for a typical selective kill in a relatively small impoundment.

GPS tracking should be used to monitor the application transects. Transect spacing should be narrowed as the application progresses, with the applicator halving the distance between previous transects with each pass. Application speed should be sufficient (2–5 mph) to minimize localized "hot spots" that may occur if application speed is too slow. A graphic description of a "typical" GPS track recorded during an application is pictured Figure SOP 5.1.

Deep-water applications should be used in lake zones where water depth exceeds 20 feet. This will reduce the likelihood of over-application at the surface. Application will be similar to the method described above; however, the terminal end of the apparatus will be fitted with a weighted nozzle to diffuse applied material that trails the boat at the appropriate depth (see Figure SOP 5.2). Deep water applications are typically performed at approximately ½ speed due to the use of the suspended application hose.

Table SOP 5.8. Lake volume (AF) and rotenone formulation (5% a.i.) needed for elimination of Gizzard Shad at a rotenone treatment rate of 8.0 ppb (see Figure SOP 5.1 for location and size of zones).

Location	AF	Total Rotenone Formulation (ml)	Quantity of Formulation/Tank (ml)
Zone 1 < 20'	105.58	18,474	3,695
Zone 1 > 20'	29.54	5,169	1,034
Zone 2 < 20'	49.52	8,665	1,733
Zone 2 >20'	8.15	1,426	285
Zone 3 <20'	112.53	19,690	3,938
Zone 3 > 20'	35.7	6,247	1,249
Zone 4 < 20'	154.63	27,057	5,411
Zone 4 > 20'	65.42	11,447	2,289

XI. Additional Considerations

A. Pond and Wetland Treatment

Ponds and wetlands located within the drainage of the target water body may be treated if they contain target species. Failure to remove these species could result in reinvasion of the target organism. In most cases, a complete treatment of these systems is preferred, followed by a restocking program. Wetlands with direct connection to the treated water body should be treated concurrently with the remainder of the lake at the selected treatment concentration.

B. Drinking Water Supply

Applicators must comply with the advisory and monitoring requirements on the label when treating a drinking water supply. Selective treatments will likely not exceed 15 ppb and should therefore be safely under this threshold. Cooperation with any water provider is imperative to ensure accurate dissemination of information to the public.

VII. Additional Information

Bowers, C. C. 1955. Selective poisoning of Gizzard Shad with rotenone. The Progressive Fish Culturist 17:134–135.

Flammang, M. K. 2014. Use of low-concentration rotenone for biomanipulation of Iowa lakes. Iowa Department of Natural Resources, Job Completion Report. Des Moines, Iowa.

Gilderhus, P. A. 1972. Exposure times necessary for antimycin and rotenone to eliminate certain freshwater fish. Journal of the Fisheries Research Board of Canada 29:199–202.

Marking, L. L., and T. D. Bills. 1976. Toxicity of rotenone to fish in standardized laboratory tests. Investigations in Fish Control 72.

Wisener, J. R. 2005. Glenn Flint Gizzard Shad Selective. Job completion Report. Fisheries Section, Indiana Department of Natural Resources Division of Fish and Wildlife. Indianapolis, Indiana.

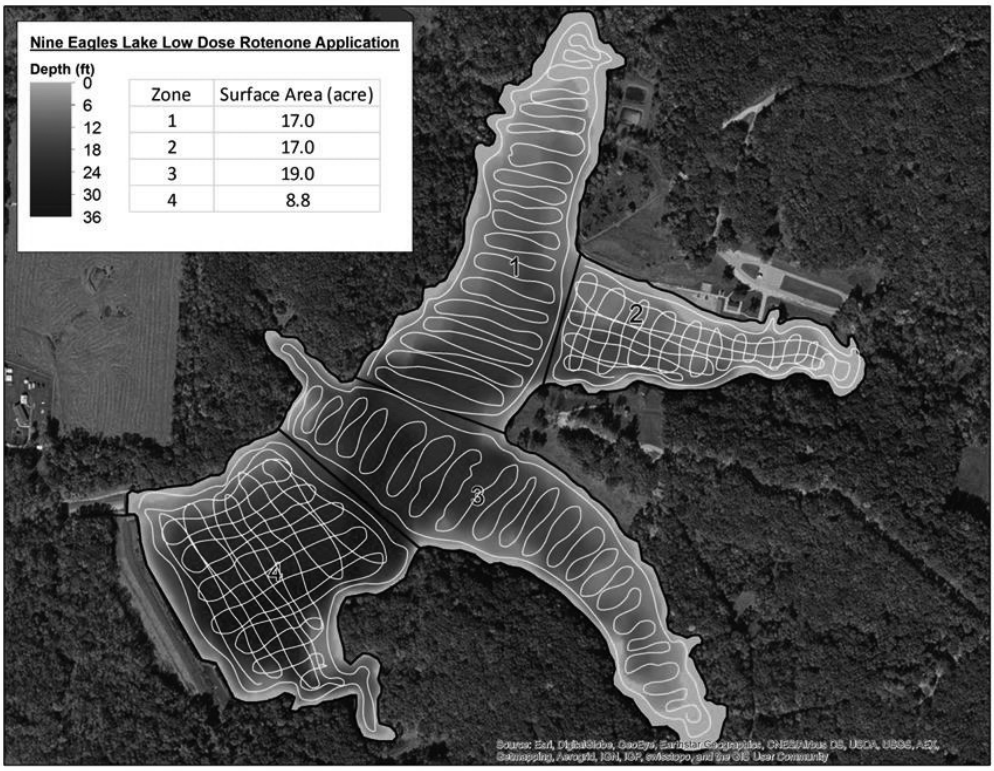


FIGURE SOP 5.1. Typical GPS track and lake zonation for a selective application detailed in Table SOP 5.8.

FIGURE SOP 5.2. Example of a weighted diffusion nozzle for deep-water applications.

Treatment Areas and Project Areas
SOP: 6.1

PURPOSE: Provide criteria for determining the treatment and project areas to assure public safety and legal requirements are met

PROCEDURE:

I. Determining Treatment Area

The Treatment Area is the water body where rotenone is applied as a means of control or eradication of the target species, and should be described in a written treatment plan (refer to Chapter 2). For stream treatments with multiple drip stations, the downstream end of the Treatment Area will be the point below the lowermost drip station where killing of fish is no longer desired, typically where a deactivation station is positioned. Exceptions to this definition include: (1) where the stream goes subsurface below the last drip station, then the point where surface flow ceases becomes the lower margin of the Treatment Area; or (2) where rotenone-free surface flow joins the treated water and results in a dilution that is below detection (<0.002 ppm rotenone), then the point of confluence becomes the lower margin of the Treatment Area. Activities restricted to the Treatment Area include:

- Wash or rinse all application equipment in the Treatment Area (see "Environmental Hazards" on the label)
- Workers re-entering Treatment Areas where applications are >0.09 ppm rotenone refer to "Placarding of Treatment Areas" and "Re-entering the Treatment Area" under "Directions for Use" and SOP 1.1 for information on when placards and protective PPE are no longer required.
- Recreational access is not allowed within the Treatment Area during the application of rotenone (see "Precautions and Restrictions" under "Directions for Use" on the label)
- For applications >0.04 ppm rotenone in waters with drinking water intakes or hydrologic connections to wells, certain notifications and monitoring requirements apply (see "Monitoring and Notification Requirements for Water" under "Directions for Use" on the label and SOP 16.0).

II. Determining Project Area

The Project Area is not defined by the label but is a useful demarcation of the impacted area for which effects are analyzed during the environmental analysis. The Project Area includes the Treatment Area plus the deactivation zone down to the point where you expect fish or other aquatic

organisms to survive and rotenone to be undetectable by chemical analysis. It also includes groundwater areas in hydrologic connection that would be affected by rotenone application and deactivation. Guidance for determining the potential for hydrologic connection is provided in SOP 16.1. The Project Area should be defined in a written treatment plan (see Chapter 2).

The Project Area will also include the land adjacent to the Treatment Area where human activities related to the use of rotenone can occur. These include staging areas for equipment and personnel, storage of chemicals, camping/cooking areas, trash/refuse areas, location of pack stock, and helicopter landing spots. The restrictions on recreational use in the Project Area should be the same as those in the Treatment Area (see "Placarding of Treatment Areas" under "Directions for Use" on the label and in SOP 1.1). Activities restricted to the Project Area include:

- The Certified Applicator must remain in the Project Area during the rotenone application phase of the treatment
- If a hydrologic connection exists for domestic wells within Project Area, notification to users must be provided 7–14 days prior to application (see "Monitoring and Notification Requirements for Water" under "Directions for Use" on the label and in SOP 16.1).
- For applications >0.04 ppm rotenone in waters with drinking water intakes or with hydrologic connections to wells, certain notification and monitoring requirements apply (see SOP 16.1). This applies to drinking water intakes and wells within the Project Area.
- The deactivation zone within the Project Area should be posted with the same placards as used for the Treatment Area, and should remain posted until deactivation ceases (see SOP 1.1)
- If concentrations exceed 0.09 ppm rotenone, then PPE should be worn in both the Treatment Area and Deactivation Area as referenced in "Re-entering the Treatment Area" under "Directions for Use" on the label and in SOP 3.1.

Chemically Induced Deactivation
SOP: 7.1

PURPOSE:

1. Remove rotenone and effects to non-target organisms beyond the Treatment Area (see SOP 6.1)
2. Provide a protocol for successful deactivation

PROCEDURE:

I. Need for Chemically-Induced Deactivation

Good rotenone stewardship results from the prudent use of the product by taking responsibility for reducing environmental impacts. Consistent with this, in flowing systems treated water must be deactivated with potassium permanganate ($KMnO_4$) downstream of the Treatment Area (see SOP 6.1 for definition) since real-time measurements of rotenone concentrations are not possible to document that detectable levels of rotenone (≥2 ppb) are confined to the Treatment Area. However, consistent with the product label, the response of bioassay sentinel fish can be used as a surrogate. Deactivation can be terminated when replenished sentinel fish survive and show no signs of stress for a minimum of four hours.

Standing water bodies typically do not need to be deactivated unless there is a discharge to surface waters. In this situation, the outlet water itself is deactivated but it is permissible to deactivate standing waters directly. This approach should only be considered if the duration of deactivation of the outlet waters would be excessively prolonged.

II. Methods for Chemically-Induced Deactivation

It is recommended that staff experienced with deactivation techniques supervise the deactivation component of rotenone treatments, as this process is critical to avoid unplanned downstream impacts. Potassium permanganate ($KMnO_4$) is the only chemical allowed for deactivating rotenone on product labels and is applied in granular form or as a 2.5% solution (1 pound $KMnO_4$ to 5 gallons (25 g/L) water). A 2.5% solution assures that $KMnO_4$ remains in solution at most water temperatures. The solubility in distilled water is 1.8 pounds $KMnO_4$/5 gallons (43 g/L) water at 10°C and 2.7 pounds $KMnO_4$/5 gallons (65 g/L) water at 20°C.

Deactivation activity increases directly with increase in temperature, and applicators should take into account that chemical reactions slow by 50% for each 10°C reduction in temperature and increase by about 2-fold for each 10°C increase (Q10 rule). This is important in determining the stream reach or surface are and deactivation lag times at very low temperatures. For example, approximately twice the contact time will be required at a temperature of 5°C than at 15°C with the same level of $KMnO_4$.

$KMnO_4$ is toxic to fish (see SOP 14.1) at relatively low concentrations under some circumstances and is more toxic in alkaline water than soft water (Marking and Bills 1975). If $KMnO_4$ concentrations are in balance with rotenone concentrations, then toxic levels of $KMnO_4$ are reduced through the oxidation of organic components and rotenone.

A. Application Rates

Deactivation of rotenone is a time-dependent reaction; the time the two chemicals are in contact dictates the effectiveness or degree of deactivation. Engstrom-Heg (1972) developed time-lapse curvilinear relationships for deactivating Noxfish (5% a.i. formulation) concentrations over a range of $KMnO_4$ concentrations in soft water (pH = 6.8 and alkalinity = 14 ppm CaCO3). Rotenone is deactivated with $KMnO_4$ at approximately a 1:1 (ppm $KMnO_4$: ppm Noxfish) ratio, when the contact time ("cutoff" in the Figure SOP 7.1) is about 60 minutes. As the contact time is shortened, the ratio of $KMnO_4$: rotenone increases. For example, at 30-minutes contact time, the ratio is 1.5–2.0:1.0. The 30-minute contact time is recommended for most stream treatments to assure deactivation. Shorter contact periods are less efficient and problematic because greater amounts of $KMnO_4$ are required, resulting in higher levels of residual $KMnO_4$ that travel downstream from the Project Area. Contact periods greater than 30 minutes may be problematic because it is difficult to maintain $KMnO_4$ residues in the water column without booster stations.

Another important consideration is that dissolved electrolytes, aquatic plants, dissolved and suspended organic matter, and streambed materials increase the amount of KMnO4 required. These contribute to the background "oxygen demand" of water that typically ranges from 1–4 ppm for 30-minutes contact time. At one extreme, water flowing over granitic bedrock surfaces may have a demand of only 1 ppm KMnO4, while in karst or limestone landscapes, streams with watercress and dissolved organics may have a demand of 4 ppm.

The ability to measure $KMnO_4$ in the stream is central to assuring that sufficient material has been applied for deactivation and that rotenone is deactivated. More $KMnO_4$ than is necessary to deactivate rotenone is applied to yield a measurable $KMnO_4$ residual at the end of the 30-minute contact zone, and this assures that rotenone is deactivated to non-detectable levels (<2 ppb rotenone) at the end of the 30-minute contact time. For simplicity, it is recommended that a residual level of 1 ppm $KMnO_4$ be maintained at the end of the Deactivation Zone. This is a level not likely toxic to fish, but can be measured by most commercial devices and is also easily visible to the unaided eye. For example, the application rate of 3 ppm $KMnO_4$ is normally required for a 30-minute contact zone to deactivate 1 ppm Prenfish (or equivalent 5% a.i. formulation):

1 ppm $KMnO_4$ is needed to deactivate 1 ppm Prenfish
+
1 ppm $KMnO_4$ is needed for background oxygen demand in water
+
1 ppm $KMnO_4$ residual is needed at the 30-minute travel-time mark.

It is only through experience and knowledge of local conditions, soils, and rock types that the Certified Applicator will be able to closely predict the oxidizing demand of a stream, lake, or pond. In most circumstances, it will be necessary to use professional judgment in selecting an initial concentration. In addition, conditions such as rain and subsequent runoff during deactivation may increase the amount of $KMnO_4$ needed during a given treatment.

B. Application Methods

Deactivation is a dynamic operation that presents some difficulties in managing application rates and predicting rotenone concentrations. Certified Applicators should consider using a second fully functional, redundant (i.e., backup) deactivation station positioned downstream from the effective reach of the primary deactivation station.

Deactivation procedures should begin at a minimum of several hours before the onset of rotenone application to ensure that no rotenone passes the deactivation station and to reduce $KMnO_4$ demand of the streambed immediately downstream from the deactivation station. This will ensure the streambed is fully oxidized, measuring free $KMnO_4$ of at least 1.0 ppm at the 30-minute biomonitoring station prior to contact with rotenone. Alternatively, determine the time (sometimes with dye) when rotenone is expected to arrive at the deactivation station and begin application of $KMnO_4$ at that time. Note that it takes a minimum of 1–2 hours of $KMnO_4$ application for most substances in the streambed to become oxidized in the contact zone and thus, there is less $KMnO_4$ available to reduce rotenone within the first several hours of operation.

Generally, caged sentinel fish are placed above the point of $KMnO_4$ injection and at the end of the 30-minute contact zone. Placing caged sentinel fish at the 15-minute contact time point may help with interpreting the progress of deactivation within the Deactivation Area. If $KMnO_4$ levels are on target, fish at the 30-minute contact time will survive and those at 15-minute contact time will show signs of stress but may take many hours to die. Another location for caged sentinel fish farther downstream at a distance of 45 or 60-minutes contact time may help in judging the effectiveness of deactivation.

The effectiveness of the deactivation is measured by the ability of caged sentinel fish to survive in water downstream from the 30-minute contact zone and by maintaining a 1 ppm $KMnO_4$ residual. A 1 ppm residual $KMnO_4$ is not toxic to trout at exposures of less than 96 hours, but $KMnO_4$ levels above 1 ppm will stress fish. Thus, mortality of fish at this location is likely attributable to rotenone, $KMnO_4$ and other factors such as confinement stress. Replace caged sentinel fish daily at this location where practical because of confinement stress in flowing water.

Measurements of residual $KMnO_4$ are taken periodically to ensure the residual level of 1 ppm is present at the end of the 30-minute contact zone (see Section D in this SOP). Deviations can be addressed by increasing or decreasing the rate of application of $KMnO_4$ to the stream. Measurements every half hour are usually necessary at the beginning of the treatment, but are scaled back to every 1–2 hours once equilibrium is achieved. Normally, the $KMnO_4$ demand within the deactivation zone decreases over the duration of the treatment as monitored by the residual $KMnO_4$ at the end of the 30-minute contact zone. It is beneficial to have the deactivation station in constant contact (e.g., two-way radios) with the person(s) doing the $KMnO_4$ monitoring so adjustments can be made instantly, if necessary. The amount of $KMnO_4$ required will decrease as rotenone residues dissipate over time.

Continue deactivation until the water directly upstream of the deactivation station can sustain fish in an unstressed state in a bioassay for a minimum of 4 hours (see SOP 14.1). Use caution with target species bioassay fish at this location unless the end of the deactivation zone is below a fish barrier, especially if this is the last of a series of treatments. Sentinel fish that escape cages will not compromise the success of the treatment if it is below a fish barrier. If the end of the deactivation zone is not below a barrier, consider using the fish species that will be reintroduced into the stream for the bioassay, if available.

Continual maintenance of the deactivation station(s) is required throughout the treatment. On streams, at a minimum, expect to run this operation for the duration of the treatment plus the travel time from the most upstream point of the Treatment Area downstream to the deactivation station. For outlets from standing bodies of water, deactivation may be required for days or even weeks, and will depend on how quickly the treated water is diluted by inlet water (retention time) and the rate of rotenone degradation, which will be slowed by low water temperatures and/or low ambient solar radiation. Ensure that sufficient staff are available to provide assistance as needed for breaks, errands, and loading and monitoring fish cages. Each worker maintains a log of activities, application rates, and observations to assure that prescribed procedures are followed and for future reference.

The circumstance may arise where it is necessary to treat a stream all the way to its confluence with a larger receiving water stream. In some cases, the discharge of the larger receiving water will not be sufficient to dilute rotenone to non-detectable (<2 ppb rotenone) levels. A deactivation station placed very close to the mouth of the smaller stream may result in a travel time too little for adequate contact between rotenone and $KMnO_4$ to render the treated water to non-detectable levels before being diluted in the receiving water. This is because once in the receiving water, the $KMnO_4$ may be diluted to the point where it is insufficient to deactivate the rotenone. In this case, apply $KMnO_4$ at the rate based on the combined flow of the treated and receiving water. This approach ensures that even in the combined waters there will be enough $KMnO_4$ to deactivate the rotenone for a full 30-minute contact time.

Circumstances that might provide certainty that deactivation may not be necessary include: a) where non-treated waters within the Treatment Area can serve to dilute treated water to a calculated level <2 ppb rotenone; or b) where the Treatment Area ends at a location where the stream goes dry. In both cases, the rotenone concentrations below the Treatment Areas are <2 ppb.

C. Application Equipment

Dispense $KMnO_4$ in liquid (see SOP Figure 7.2) or solid (See SOP Figure 7.3) form. Liquid solutions should consist of 1 pound solid $KMnO_4$ mixed into 5 gallons (25 g/L) water. Most liquid applications use a reservoir with a metering device to dispense at a constant measurable rate. However, varying conditions during treatment (changing discharge rates, rotenone concentration, and oxygen demand) may require a change in the dispensing rate of $KMnO_4$, and use of a metering device that can be manually adjusted (see SOP Figure 7.2). A 2.5% $KMnO_4$ solution is dispensed at a constant concentration using the equation:

For ft^3/s:

LF = Y • 70 • Q where, LF = flow of 2.5% $KMnO_4$ solution (ml/min), Y = desired $KMnO_4$ concentration in stream (ppm) and Q = stream discharge (ft^3/s) or

For m^3/s:

LF = Y • 2,472 • Q where, LF = flow of 2.5% $KMnO_4$ solution (ml/min), Y = desired $KMnO_4$ concentration in stream (ppm) and Q = stream discharge (m^3/s).

Application of solid $KMnO_4$ is typically done with a device that meters the material out of a reservoir (or hopper) directly into the water (see SOP Figure 7.3). Again, the metering device should be adjustable. $KMnO_4$ crystals can be added to the stream using a mechanical auger of other device using the equation:

For ft^3/s:

SF = Y • 1.7 • Q where, SF = flow of solid KMnO4 crystals (g/min), Y = desired KMnO4 concentration in stream (ppm) and Q = stream discharge (ft^3/s) or

For m^3/s:

SF = Y • 60.02 • Q where, SF = flow of solid $KMnO_4$ crystals (g/min), Y = desired $KMnO_4$ concentration in stream (ppm) and Q = stream discharge (m^3/s).

The advantage of liquid formulation application is that the devices require no electricity to run and are very mobile; thus, these applications are well suited to remote locations with no power or road access. The disadvantages for liquid application are that it requires a large reservoir or making large amounts of liquid for streams with large discharges or if deactivation is extended for many days. Also, the liquid can freeze in the discharge line/valve under freezing conditions; this can be alleviated by placing a heat producing source (i.e., gas lantern) underneath the line/valve. The advantage for solid formulation application is that a large reservoir is not needed and the metering device is typically extremely accurate. The disadvantage for solid formulation application is that the equipment is heavy, unwieldy and needs electricity and thus best suited to areas with road access and deactivation of high discharge streams.

D. Measuring Potassium Permanganate

$KMnO_4$ can be measured directly in the field using several analytical techniques. The most accurate method is to make a standard spectrophotometric curve that plots absorbance (at 525 nm) for solutions of known $KMnO_4$ concentration. Samples taken in the field during treatment are measured for absorbance on a portable spectrophotometer, and concentrations can be estimated by reading off the standard curve. See Standard Method 4500-$KMnO_4$ B for details (American Public Health Association 1998).

A less accurate estimate of $KMnO_4$, but an easier approach, is the DPD (N, N-diethyl-p-phenylenediamine sulfate) method for measuring total chlorine. Through the introduction of a powder containing DPD, potassium iodine and a

buffer, the oxidizing potential of the solution is measured spectrophotometrically or using a color wheel. The oxidizing potential of $KMnO_4$ is about 89% of total chlorine, so results from this method can be multiplied by 0.89 to get an approximate measure of $KMnO_4$ concentrations in water (see Hach Chemical Company Method 8167).

III. Additional Information

American Public Health Association. 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, Washington, D.C.

Engstrom-Heg, R. 1972. Kinetics of rotenone-potassium permanganate reactions as applied to the protection of trout streams. New York Fish and Game Journal 19(1):47–58.

Marking, L. L., and T. D. Bills. 1975. Toxicity of potassium permanganate to fish and its effectiveness for detoxifying antimycin. Transactions of American Fisheries Society 104:579–583.

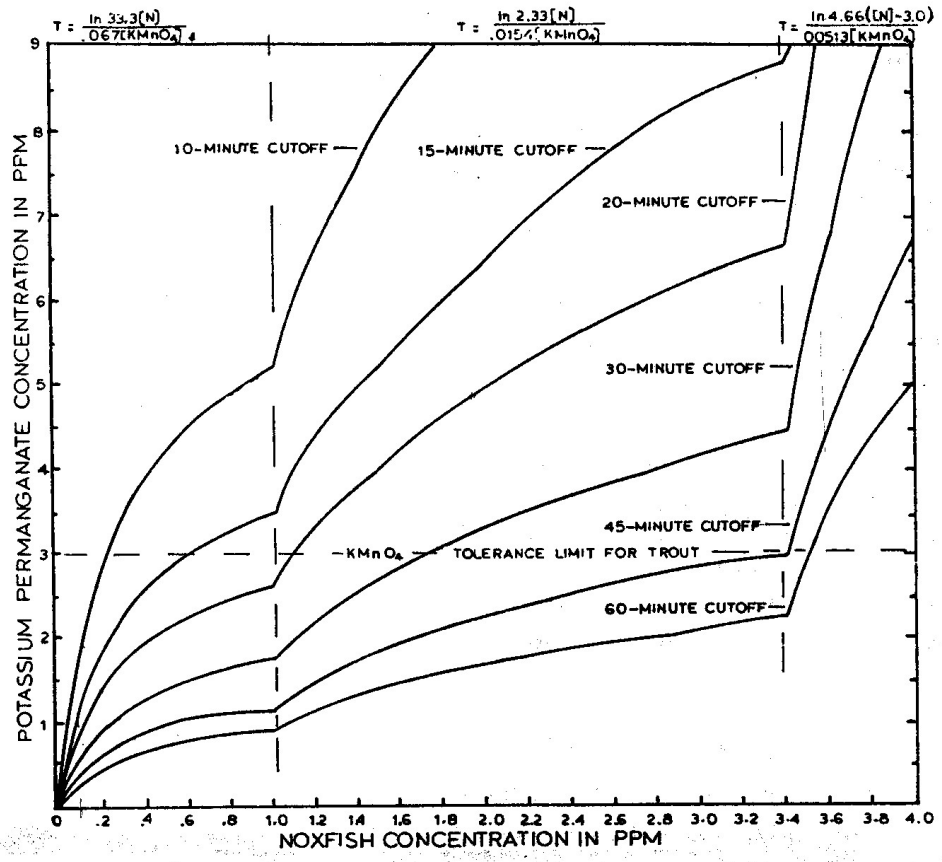


Figure 5. Relationship between Noxfish concentration, potassium permanganate concentration and contact time required for detoxification.

FIGURE SOP 7.1. Time required (contact-time) for potassium permanganate to deactivate rotenone from Engstrom-Heg (1972). Chart can be used to determine the concentration of potassium permanganate needed to deactivate a known concentration of Noxfish (5% a.i. formulation) at a given contact-time in soft water (pH = 6.8 and alkalinity =14 ppm $CaCO_3$) and a temperature of 65 °F (18.5 °C).

FIGURE SOP 7.2. Dispensing liquid 2% $KMnO_4$ solution into the main flow of a stream. Note the manually controlled spigot for controlling the flow of the solution and the large stoppered hole used for filling the dispensing barrel.

FIGURE SOP 7.3. Dispensing granular $KMnO_4$ into the flow of the stream with an electronically controlled auger. Once calibrated, the auger can dispense the granules at various constant rates. Note the wooden platform built out over the rocks in the flowing stream and a small gasoline generator to power the auger behind the technician.

Semi-Closed Probe Systems for Application of Liquid Rotenone SOP: 8.1

PURPOSE:

1. Mitigate for occupational exposure to liquid rotenone
2. Provide guidance on the design and operation of semi-closed probe systems for application of liquid rotenone typically used in large projects

PROCEDURE:

The semi-closed probe system allows for the transfer of liquid rotenone directly from the drum to the mixing tank/application device with the use of a suction hose connected to one end of the suction pump on the mixing tank/application device and connected at the other end to a probe/dip tube. The rotenone diluted and mixed in the pump head and discharged to site water without applicator contact.

I. Preparation

Ensure that bungs are tight. Stand drum with top end and bungs pointed up. Then tip drum over carefully and roll back and forth to suspend any settled material at the bottom of the drum.

Stand drum on the ground or a secure level platform with top end and bungs pointed up. Then remove 2″ or ¾″ plug from bung of drum.

Do not pour liquid rotenone directly from a drum greater than 5 gallons (see SOP 10.1).

II. Operation

Remove the 2″ or ¾″ plug from bung of drum and insert the probe/dip tube into the bung hole until the foam ring/gasket (not provided by manufacturer) on the probe fits snugly around the bung hole to minimize leakage of liquid rotenone.

Size the metal or chemically-resistant plastic probe/dip tube for a snug fit into the bung when a foam ring/gasket is attached. The anti-drip flange of the barrel (curved inward towards bung) ensures that excess liquid rotenone returns to the barrel when the probe/dip tube is removed.

Attach a matching chemically-resistant rigid hose to the probe/drip tube to suck the liquid rotenone from the drum into the pump head for mixing with site water. Shut-off valves are located at the probe/dip tube end and at the pump end (see Figures SOP 8.1 and 8.2). These valves control the mix of rotenone liquid to site water (1 part rotenone : 9 parts site water (10%) is recommended dilution) for quick dispersion in standing waters. Calibrate the semi-closed delivery system before use for the correct dilution rate.

Do not handle the probe/dip tube in a manner that allows dripping or splattering of the liquid rotenone onto yourself or any other person. Do not touch the portion of the probe/dip tube that has been in contact with this product until the probe has been triple rinsed with water.

Applicants using a boom or other mechanized equipment must discharge rotenone below the water surface.

Applicants using hand-held or hand-directed nozzles may release rotenone above the water surface. Operate hand-directed nozzle in a manner to minimize small droplets and reduce drift. A large volume of water relative to the amount of rotenone formulation minimizes drift. A large diameter orifice on the spray nozzle, spraying with the prevailing wind, reducing the distance sprayed from the nozzle, and directing the spray towards the water surface all minimize drift.

Triple-rinse the intake drip tube while it remains inside the drum (if possible) once all the liquid rotenone has been removed from the drum. This can be accomplished by adding site water through the other bung hole, either manually or using the water pump and another hose on the outlet structure. If an unrinsed intake drip tube is removed from the drum, triple rinse it and all parts of the aspirator in treated site water.

Take the following steps if the probe/dip tube must be disconnected from the suction hose before both the probe and the hose have been triple-rinsed: (1) equip the probe end of the hose with a shutoff valve; (2) install a dry disconnect or dry brake coupling (see Figure SOP 8.3 for example) between the valve and the probe, and; (3) close the shutoff valve before disconnecting the probe.

III. Safety

Mixers, loaders, and applicators using all systems must wear PPE as described on the product labeling.

All systems must be capable of removing the pesticide from the shipping container and transferring it into mixing tanks and/or directly to the application equipment.

At any disconnect point, the system must be equipped with a dry disconnect or dry couple shutoff device to minimize dripping (see Figure SOP 8.4).

IV. Application

With properly operating semi-closed systems, the liquid formulation is diluted in the pump head and boats can apply diluted rotenone underwater (see Figure SOP 8.4) or as a diluted spray using a hose and hand-directed nozzle (see Figure SOP 8.5).

V. Equipment

A. Mixing Equipment

Use a high-pressure (i.e., 60 to 70 psi) centrifugal self-priming water pump (2 to 3 inch) sufficient to pump water and create a vacuum to draw liquid rotenone from its container. The pump functions as the ‘mixing tank’ to combine water from the intake hose and the liquid rotenone. Examples include Honda WH20XK1AC1 or Berkeley B1-1 pumps.

Use a high-pressure (i.e., 100 to 150 psi) water intake hose or plastic pipe. The intake hose/pipe is attached to a T-coupling having the liquid rotenone intake suction hose attached at the distal end (see Figure SOP 8.1). Screen the distal end of the water intake hose to reduce the amount of vegetation and/or debris entering the hose (see Figure SOP 8.2).

Attach a valve at the distal end of the liquid rotenone intake suction hose (i.e., ½ or 1½ inch diameter). The valve controls the rate of liquid rotenone flow into the water intake. The probe is inserted through a foam or rubber ring or gasket into the bung hole of the drum (see Figure SOP 8.2).

A water outlet hose (2 to 3 inches diameter) normally applies the diluted and mixed rotenone underwater (see Figure SOP 8.4) unless connected to a spraying device (see Figure SOP 8.5).

B. Hand-directed Nozzle

The dilute mixture of rotenone can be directed to a nozzle for spraying shallow or inaccessible waters (see Figure SOP 8.5). A brass straight stream nozzle is attached to a rotating monitor, which is mounted to the boat deck or cowling (see Figure SOP 8.6). A shut-off valve is between the outlet hose/piping and the nozzle.

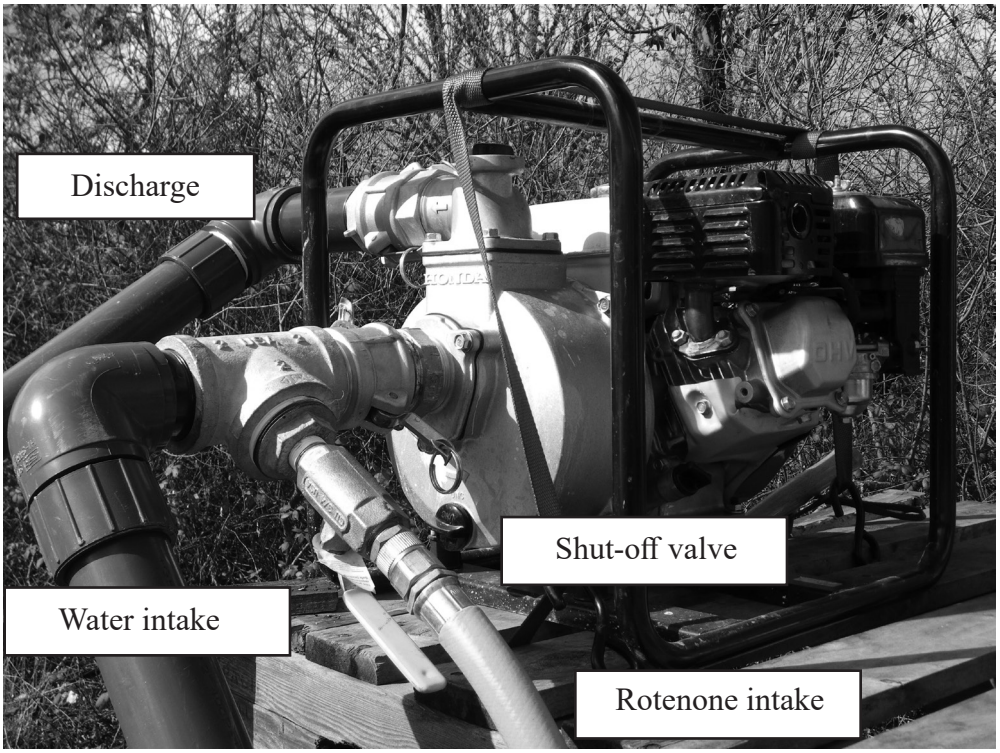


FIGURE SOP 8.1. Two-inch gasoline-powered water pump showing arrangement of intake and discharge hoses and shut-off valve (Photo credit: Holly Truemper, Oregon Department of Fish and Wildlife).

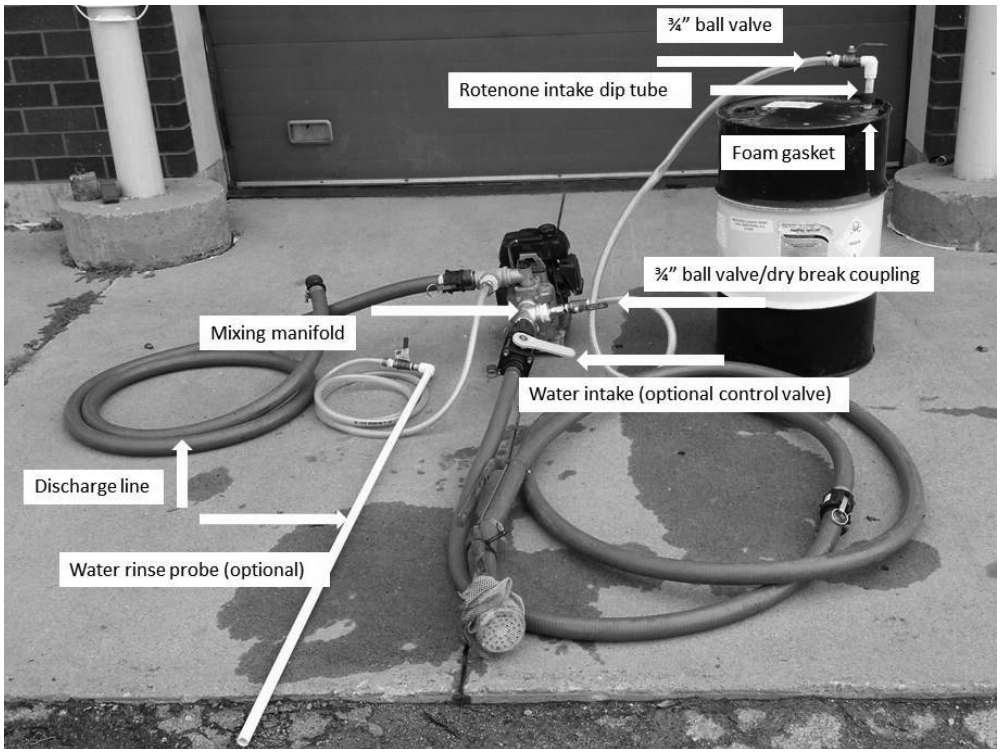


FIGURE SOP 8.2. Arrangement of site water intake, discharge hoses, rotenone liquid probe/drip tube, and optional water intake control valve for greater control of application concentration (Photo credit: Mark Flammang, Iowa Department of Natural Resources).

FIGURE SOP 8.3. An example of a dry disconnect valve showing the two halves coupled together with cam arms. Two interlocking handles make opening and closing easy. When liquid is flowing, disconnect valve halves cannot be uncoupled without turning handles to closed position. When disconnect valve halves are apart, handles cannot be turned to open position.

FIGURE SOP 8.4. Application of liquid rotenone below waterline using semi-closed application system at Diamond Lake, Oregon (Photo credit: Brian Finlayson, California Department of Fish and Game).

FIGURE SOP 8.5. Application of liquid rotenone using semi-closed application system with spray nozzle to shallow waters of Park Lake, Grant County, Washington (Photo credit: Jeff Korth, Washington Department of Fish and Wildlife).

FIGURE SOP 8.6. Examples of monitors (firefighting equipment) and suggested nozzle.

Semi-Closed Aspirator Systems for Application of Powdered Rotenone SOP: 9.1[1]

PURPOSE:

1. Mitigate for occupational exposure to powdered rotenone
2. Provide guidance on the design and operation of semi-closed aspirator systems for application of powdered rotenone for fish control

PROCEDURE:

The semi-closed system sucks powdered rotenone directly from the product container, mixes it with the water from the treatment site in the aspirator, and then discharges the slurry at or slightly below the waterline. A high-pressure pump forces water through the aspirator creating sufficient suction to vacuum powdered rotenone from containers. Discharge slurry directly to the water at or below surface or above the surface through a hand-directed nozzle as a spray. The semi-closed aspirator system significantly reduces airborne rotenone dust.

I. Preparation

Place powdered rotenone container on an impermeable surface, such as a tarp or concrete ramp at the water's edge, so spillage can be safely flushed into the treated water.

Roll the sealed container on the ground to loosen the rotenone powder that may have settled during shipping and storage.

Remove the plug from bung of the container liner enclosing this product when the container is sitting on the ground or on a secure level platform, with the bung end of the container pointed up.

Handle the powdered rotenone formulation in a manner that will not result in an excessive amount of airborne rotenone dust/powder.

II. Operation

Start the pump and establish water flow through the aspirator to achieve venturi suction.

Size the metal or chemically-resistant plastic probe/dip tube for a snug fit into the bung when a foam ring/gasket is attached.

Remove top of the container, remove plug from bung of the plastic liner, and insert probe until the foam ring/gasket on the probe fits snugly around the bung opening in the plastic liner.

[1] The new packaging for powdered rotenone will be available in the future. SOP 9.1 will be revised to reflect changes caused by the product packaging. Check for revised SOP 9.1 at http://rotenone.fisheries.org.

Transfer product from the container with the use of the probe/dip tube attached to the suction hose through the top of the aspirator. The aspirator is connected to the discharge side of the suction pump.

Maneuver the probe/dip tube by hand to suction powdered rotenone from the container. Handle the probe/dip tube in a manner that minimizes the dispersing of rotenone powder onto you, any other person, or into the air. Apply the required amount of rotenone to ensure that the powder is dispensed evenly across the treatment area.

Remove the probe/dip tube when the entire contents of the container have been removed. Let the probe/dip tube suck air for 30 seconds prior to applying powdered rotenone from the next container.

Do not attempt to triple rinse the probe/dip tube and suction hose with water until the entire application has been completed. Make sure equipment is completely dry after cleaning before reusing. A wet/damp probe/dip tube and suction hose will lead to the powder caking and reducing the suction capacity of the aspirator system.

After the application is complete and the aspirator probe is removed from the container, there will be residual powder remaining in the container. Reseal the container for later application and/or rinsing.

Liners are triple-rinsed by removing from the container, submerging the liner before cutting open, and wetting the liner underwater. Conversely, a wash-down pump and line may be used to safely and effectively triple-rinse the liners and containers. The wash line should be inserted into the bung hole, wetting the powder, and the slurry can then be rinsed directly into the treated water.

Following treatment, deployment equipment should be emptied, triple-rinsed with water to remove residue, disassembled, collected, and stored in accordance with the product label. Clean equipment where rinse water can be effectively disposed into the treatment site. Make sure all equipment, especially the aspirator and suction hose, is completely dry prior to the next application. The operation of the aspirator can be checked with dry, fine grain sand.

III. Safety

Personal Protective Equipment: mixers, loaders, applicators and other handlers must wear PPE as required on product labeling (see Figure SOP 9.1).

All systems must be capable of removing the powder from the shipping container for application and transferring it into mixing tanks and/or application equipment.

IV. Application

With properly operating semi-closed systems, boats can apply powdered rotenone efficiently (see Figure SOP 9.2).

V. Equipment (Figure SOP 9.3)

Examples of pumps that have worked well for project personnel: Gorman-Rupp series 60 centrifugal model with an enclosed impeller, or equivalent, coupled to a Briggs and Stratton twin cylinder, 18 HP, air cooled gasoline engine. Pump is rated at 150 GPM at 65 feet of head.

Hale transportable fire pump coupled to a Briggs and Stratton Vanguard series 350400 V Twin, overhead valve, air cooled design, rated at 18 BHP at 4000 rpm with a torque of 30 lb-ft at 2600 rpm. Pump is rated at 150 GPM at 100 psi.

Hoses—Water intake and slurry delivery hose is a high-pressure hose, rated at 100 to 150 psi, recommended for delivering water from the pump to an aspirator. Use a screen at the distal end of the water intake hose to reduce the amount of vegetation and/or debris entering the hose. Use a weight attached to the distal end of the water intake hose to keep the hose in the water.

Aspirator—Aspirator is manufactured with readily available plumbing connectors and pipe (Figure SOP 9.4). Mount aspirator directly to pump outflow for best suction through powder suction probe/dip tube and efficient mixing of rotenone and water slurry.

VI. Additional Information

Finlayson, B. J., R. A. Schnick, R. L. Cailteux, L. DeMong, W. D. Horton, W. McClay, C. W. Thompson, and G. J. Tichacek. 2000. Utah's rotenone aspirator system. Appendix L *in* Rotenone use in fisheries management: administrative and technical guidelines manual. American Fisheries Society, Bethesda, Maryland.

Thompson, C. W., C. L. Clyde, D. K. Sakaguchi and L. D. Lentsch. 2001. Utah's procedure for mixing powdered rotenone into a slurry. Pages 95–105 *in* R. L. Cailteux, L. DeMong, B. J. Finlayson, W. Horton, W. McClay, R. A. Schnick, and C. Thompson, editors. Rotenone in fisheries: are the rewards worth the risks? American Fisheries Society, Trends in Fisheries Science and Management 1, Bethesda, Maryland.

FIGURE SOP 9.1. Powered air-purifying respirators used in applying powdered rotenone to Williams Lake, Washington (Photo credit: Chad Jackson, Washington Department of Fish and Wildlife).

FIGURE SOP 9.2. Application of powdered rotenone using semi-closed aspirator system to Williams Lake, Washington (Photo Credit: Chad Jackson, Washington Department of Fish and Wildlife).

Figure SOP 9.3. Gasoline-powered water pump showing arrangement of intake and discharge hoses (Photo credit: Chad Jackson, Washington Department of Fish and Wildlife).

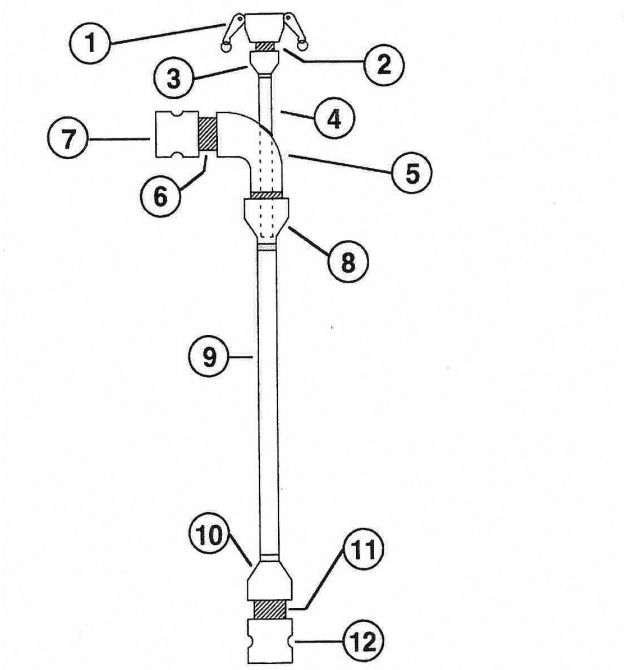


Figure SOP 9.4. Rotenone aspirator developed by Utah Division of Wildlife Resources: (1) 2” female cam lock fitting (vacuumed powder enters), (2) 2” x 2” nipple, (3) 2” x 1.25” bell reducer, (4) 1.25” x 12” nipple, (5) 3” 90 degree street elbow, (6) 3” x 3” nipple, (7) 3” male cam lock fitting (lake water enters), (8) 3” x 1.5” bell reducer (powder and water mix) , (9) 2” x 48” galvanized pipe, (10) 2” x 3” bell reducer, (11) 3” x 3” nipple, (12) 3” male cam lock fitting (powder-water slurry discharged). Rotenone aspirator was constructed of galvanized pipe (from Thompson et al. 2001).

Transferring (Mixing/Loading) Liquid Rotenone SOP: 10.1

PURPOSE:

1. Mitigate for occupational and environmental exposure to liquid rotenone
2. Provide guidance on transferring (mixing and loading) liquid rotenone concentrate from product containers to service containers and application equipment

PROCEDURE:

I. Precautions

A. Preparations

It is good practice to mix the contents of the liquid rotenone in the barrel immediately prior to opening by rolling the drum on the ground. Do not open pesticide containers until ready for use. Ensure all personnel involved with the application are knowledgeable about rotenone's toxicity, the product label, SDS, spill contingency plan and any site-specific safety plans. All personnel coming in contact with rotenone must wear proper PPE including proper clothing and eye protection and when spraying, a NIOSH approved particulate respirator, with any R or P filter with NIOSH approval number prefix TC-84A (i.e., dust/mist respirator). Rotenone applications require pouring, diluting, pumping, mixing, and transferring the liquid formulation. Good pesticide handling practices minimize even minor spills and lead to clean, safe and efficient rotenone treatments (see SOP 3.1). Many, if not most, minor liquid rotenone spills occur when transferring liquid rotenone from one container to another. Other minor spills occur when open containers are tipped, etc. Mixers, loaders, and applicators are required to wear PPE as specified on product label.

B. Secondary Containment

Control minor spills by transferring liquid rotenone from original containers to service containers (see SOP 4.1 for requirements) or application equipment within a secondary containment area. Plastic-lined berms, tubs, kiddie pools and stock tanks are effective means of secondary containment. Consistent use of secondary containment results in fast and complete recovery of small quantities of spilled materials that are easily used at the treatment site.

To create a bermed area, soil or other suitable material (e.g., straw wattle, hay bales) can be shoveled, mounded or otherwise fashioned in a complete circle and then covered with a one-piece plastic liner capable of containing any and all rotenone. Consult the responsible land-use agency if soil excavation is required. If a spill occurs, immediately recover the spilled material by sponge, pump or other efficient

means consistent with spill contingency plan (see SOP 4.1). If appropriate, apply the spilled material to the treatment area.

Wash the secondary container or plastic liner, original container, instruments used in transfer, and measuring device with site water and dispose of the rinsate into treated site water. Carefully fold the plastic liner upon itself, being careful not to release any residual material and wash the liner in the water of the treatment area.

C. Transfer

Personnel involved with mixing and loading should transfer product from original containers to service containers or application equipment by measuring appropriate amounts into measuring devices (i.e., measuring cups or graduates) and then transferring the measured rotenone into a service container or application equipment. When application equipment is not loaded with rotenone within the secondary confinement, transfer the liquid rotenone from the service container (e.g., Nalgene bottle) to application equipment (e.g., drip can, backpack sprayer) at the application site. Do not handle this product in a manner that drips or splatters the product onto yourself or any other person.

II. Rotenone Concentrate from Product Containers $\leq$ 5 Gallons

Transfer liquid rotenone from 1-gallon and 5-gallon containers within the secondary confinement area. Pouring the product from the original container into a measuring device is allowed. Small pumps or pipette-type devices can also transfer rotenone from the original container to measuring devices. Measuring devices are a non-porous receptacle marked with the appropriate graduations (i.e., gallons, liters, ounces, milliliters, etc). Containers remain within the secondary containment during transfer.

Alternatively, 5-gallon containers have threaded bungs that can accept a faucet. Remove the factory bung and outfit the bung hole with a conventional faucet and place the container on its side on a rack fabricated for this purpose. Place the rack and drum inside of a secondary containment area and fill measuring devices by means of the faucet. It may be necessary to drill a small hole in the top of the drum to allow air to enter the container. However, this may affect the ability to recycle the 5-gallon drum and may cause storage problems with any unused portion of liquid rotenone.

III. Rotenone Concentrate from Product Containers > 5 Gallons

The product label does not permit one to pour liquid rotenone from containers >5 gallons. Transfer liquid rotenone from original container to a measuring device within a secondary containment area described above using small hand or electric drum pumps for this purpose. This will allow applicators to better control liquid transfer and eliminate minor spills. Use of such pumps can also cut down on physical strain from lifting and holding heavy containers. Spilled material can be easily recovered from the secondary containment area.

IV. Spill Containment

In the event that a spill occurs, it is of paramount importance that the spilled material be contained. See SOP 4.1 for information on Spill Prevention and Containment and a Spill Contingency Plan.

V. Additional Information

University of California, Statewide Integrated Pest Management Program. 2000. The safe and effective use of pesticides, 2nd edition. Agricultural and Natural Resources Publication 3344.

Drip Stations, Peristaltic Pumps and Propwash Venturi for Application of Liquid Rotenone SOP: 11.1

PURPOSE: Provide guidance on application of liquid rotenone to streams and rivers (drip stations and peristaltic pumps) and lakes and ponds (propwash venturi).

PROCEDURE:

I. Preparation and Safety

A. Safety

Applicators of liquid rotenone must wear PPE including coveralls or long-sleeved shirt and long pants, chemical-resistant gloves, chemical resistant footwear plus socks, and protective eyewear. When actively engaged in spraying or another activity that results in mist, the applicator must wear a NIOSH approved particulate respirator with an R or P filter with NIOSH prefix TC-84A (e.g., P100 particulate respirator NIOSH Approval TC-84A-2561). Waterproof waders may be worn in place of the chemical-resistant footwear. When in contact with the treated water or the rotenone product, all appropriate safety gear must be worn; PPE is required when manipulating or adjusting the equipment or when in contact with treated water.

B. Service Containers

Liquid rotenone is typically transferred from the product container to a measuring device and then to a service container (e.g., drip can, sprayer, tank) or application device inside of a plastic-lined (i.e., bermed) or otherwise self-contained area (see SOP 10.1). Service container labels (see SOP 4.1) must identify the following information:

- The name and address of the person or entity responsible for the container
- The identity of the pesticide in the container
- The signal word “DANGER” or “ “WARNING” in accordance with the label on the original container

Typically, the transfer from manufacturer’s container to service containers or application equipment occurs at some centralized location. However, drip cans, pumps, and service containers may be taken to the streamside application site for transfer of rotenone product.

II. Drip Cans

A. Construction

Drip cans consist of a reservoir and a delivery apparatus for the application of rotenone to flowing waters. The reservoir can be any size, made from any material but typically plastic or metal in construction, fashioned from commercially available buckets or cans, and typically hold from 3 to 10 gallons liquid. The delivery system provides regulated flow of rotenone to the stream for maintaining a constant concentration of rotenone. Some delivery systems are metered that allow for manual adjustment of the drip rate without disassembling the drip can apparatus. Several designs are commonly used (see SOP 11.1 Appendix A).

B. Operation

Rotenone is applied continuously in small amounts for extended periods of time when treating flowing waters. Non-mechanized drip stations are commonly used to accomplish this. Many agencies and organizations have developed drip stations that are designed to provide constant feed rates so that treatment concentrations will be uniform. All drip cans minimize variations in flow rate attributable to loss of head pressure due to the decreasing amount of rotenone in the container. All drip cans are subject to some variation in output and clogging and periodic rate checks and adjustment (i.e., usually 30-minute intervals) are essential to successful use. It is important to filter the water (e.g., through cheesecloth) used in the drip cans as sediment and particulate matter can clog the discharge orifice. The flow rate is checked by use of a graduated cylinder or other measuring device and a stop watch (Figure SOP 11.1).

C. Placement of Application Sites

Apply rotenone as a drip for 4 to 8 hours to flowing water. Multiple application sites are necessary along the length of the treated water to maintain the desired rotenone concentration (see SOP 5.1 for treatment rates). Application sites are generally spaced at no more than 2 hours or at no less than 1 hour water travel time intervals or based on response of sentinel fish. Typically, these conditions result in spacing the applications sites approximately 0.5 to 2 miles apart. High levels of solar radiation, increasing stream gradient, decreasing stream depth, and alkaline pH reduce the travel time that rotenone remains toxic. Similarly, increasing turbidity, submerged aquatic vegetation, and streambed organic material will bind to rotenone and reduce the required travel time to maintain toxicity.

Spacing of application sites is intended to create an overlap of rotenone exposure, i.e. rotenone sufficient to kill fish should still be present in the stream as it passes by the next application site. This overlap can potentially lead to increasing concentrations of rotenone with each subsequent application site, but two factors reduce the potential for unmanageable concentrations to reach the deactivation station. First, the deactivation station is usually located 1 to 2 hours travel time below the last rotenone application site, thereby allowing any rotenone build-up to degrade and disperse in that time. Secondly, the standard protocol for establishing the application rate of KMnO4 at the deactivation station provides a safety margin that

will protect against excessive rotenone levels (see SOP 7.1). The protocol requires that 1 ppm $KMnO_4$ residual be maintained at the end of the 30-minute contact zone between rotenone and $KMnO_4$. Since all rotenone is deactivated within 30 minutes, this residual will ensure that no rotenone passes by the downstream end of the deactivation zone. If excessive rotenone is in the system, additional $KMnO_4$ is added at the deactivation station until the 1 ppm residual is available at the end of the deactivation zone.

A non-toxic liquid dye like Rhodamine WT or Fluorescein is used to determine travel time for the placement of drip stations. Beginning at the upstream end of the Treatment Area, pour 30–50 ml in the main current and follow the leading edge of the plume downstream. As the leading edge becomes hard to distinguish, recharge with additional dye as necessary. At periodic intervals, (15–30 min), record GPS coordinates and/or flag or otherwise mark a tree or other streamside object to indicate the progression of the dye. These waypoints can then be used to position drip cans during the application of rotenone.

Applying rotenone from all the application sites concurrently will achieve the desired rotenone concentration throughout the area, and this will ensure that the entire treatment area is lethal to the target species. Rotenone overtreatment can be corrected by placing the application sites farther apart and lowering rotenone dosage at each site, and rotenone undertreatment can be corrected by placing the application sites closer together and by increasing the rotenone dosage at each site.

D. Quantity of Rotenone

The amount of rotenone needed depends on many things including the desired in stream concentration of rotenone, the treatment duration, and the discharge of the receiving water (see Table SOP 11.1) using the equations:

For ft^3/s:

$X = F1(1.692 \bullet C)$ where, X = ml/minute of undiluted rotenone formulation, F1 = flow of stream in ft^3/s, and C = desired rotenone formulation in ppm in stream or

For m^3/s:

$X = F2(59.99 \bullet C)$ where, X = ml/minute of undiluted rotenone formulation, F2 = flow of stream in m^3/s, and C = desired rotenone formulation in ppm in stream.

For flows over 25 ft^3/s (0.71 m^3/s), it is usually desirable to treat using undiluted rotenone formulation. For flows less than 25 ft^3/s, it is usually desirable to treat using diluted formulation.

Larger reservoirs (or re-filling of small reservoirs) are needed for treatments of long duration, greater rotenone concentrations, or larger streams and rivers. In practice, many applicators have reservoirs that are reused from one treatment to another. Because of this it is often desirable to either refill reservoirs as the situation dictates, or apply undiluted product.

TABLE SOP 11.1. The amount (ml) of undiluted liquid rotenone (5%) formulation needed to achieve 1 ppm formulation (0.050 ppm rotenone) concentration for 4-h, 6-h, and 8-h treatments. Multiples or fractions of the stream discharge result in multiples or fractions of the undiluted rotenone required.

Stream Discharge (ft^3/s)	Stream Discharge (m^3/s)	4-h Treatment Rotenone (ml)	6-h Treatment Rotenone (ml)	8-h Treatment Rotenone (ml)
1	0.0283	409	613	818
2	0.0586	818	1226	1635
3	0.0849	1223	1834	2445
4	0.1133	1631	2447	3263
5	0.1416	2040	3060	4080
6	0.1699	2449	3673	4898
7	0.1982	2858	4287	5715
8	0.2265	3263	4894	6525
9	0.2549	3671	5507	7343
10	0.2832	4080	6120	8160

The rotenone is dispensed from a container at a constant rate determined by the equation:

Y = V ÷ T where, Y = discharge rate of container (ml/min), V = container volume (ml) and T = treatment period of 240 min (4-h) to 480 min (8-h).

III. Peristaltic Pumps

Peristaltic pumps (9 or 12-volt) may be used in place of non-mechanized drip stations and offer advantages in certain applications. The advantages of the pumps include very stable pump rates and the ability to accommodate a wide range of stream discharge rates. These pumps will have the most utility where transport into remote areas is not problematic.

A. Construction

The pumps are light and portable, but the batteries used for power are heavy. Masterflex (obtained through Cole-Parmer) and Control Company (obtained through United States Plastic Corp.) brand pumps, have been used with good success; however other brands and sources are available.

Flow rates are controlled by adjusting the pump speed setting, by the selection of one of several available hose diameters, and by selection of a high- or low-capacity pump (Masterflex) or different diameter nipples on the end of the tubing (Control Company). By varying these three components, steady flow rates from 5 ml/min to 1400 ml/min. can be achieved with the Masterflex pump or 0.4 to 85 ml/min with the medium-flow Control Company pump. One fully charged 12-V battery will power the Masterflex Model 7518-10 pump for over 12 hours at medium feed rates. Similar pump longevity can be achieved with a 9-V battery and the Control Company pump.

B. Operation

For the Masterflex pump, the rotenone container is placed inside a secondary containment vessel alongside the stream to be treated (see Figure SOP 11.2). The pump is set up above and adjacent to the rotenone supply. Pump capacity, hose size and pump setting are all predetermined matching the desired feed rate and pre-constructed output tables. A weighted pump intake hose is placed inside the opened rotenone container and the discharge is suspended over the stream. Pre-made tripods can be used for suspending the output hose. Power is provided by a simple wiring harness connecting the pump to the battery. For the Control Company pump, the battery and pump are placed on top of the rotenone container (See Figure SOP 11.3).

The flow rate is checked by use of graduated cylinder or other measuring device and a stop watch. The flow rate is corrected by adjusting the pump speed. If flow adjustment greater than what can be achieved by changing the pump speed is needed, changing the hose diameter may be required. For the smallest of streams where flow rates less than 5 ml/min of rotenone formulation are required, the rotenone may be diluted for more accurate control prior to application into the stream. Once a steady flow rate has been achieved, flow checks and adjustments should be made every 30–60 minutes.

C. Placement of Application Sites

Use the drip station placement strategy for pump application sites.

D. Quantity of Rotenone

As with drip cans, the amount of rotenone needed depends on many things including the desired instream concentration of rotenone, the treatment duration, and the discharge (see Table SOP 11.2) of the receiving water.

Table SOP 11.2. The dispensing rate of undiluted liquid rotenone (ml/min) needed to achieve a 1 ppm formulation concentration.

Stream Discharge (ft^3/s)	Stream Discharge (m^3/s)	Flow of Undiluted Rotenone (ml/min)
10	0.283	16.92
20	0.586	33.84
30	0.849	50.76
40	1.133	67.68
50	1.416	84.60
60	1.699	101.52
70	1.982	118.40
80	2.265	135.36
90	2.549	152.28
100	2.832	169.20

IV. Venturi Boat-Bailer Systems

A. Construction

This system consists of a reservoir and a delivery system for the application of dilute liquid rotenone to standing waters. The reservoir is typically a hard plastic tank that contains the liquid rotenone formulation at a recommended pre-dilution of 1:10 (rotenone formulation:water). Pre-diluting the rotenone assists in achieving a uniform application of rotenone and avoiding "hot" spots in the waterbody.
The reservoir has an air vent system to allow the product to flow freely. The orifice of the reservoir must be fitted with a shut-off valve to which is attached to one end of a hose which extends to the venturi device. The venturi device is essentially an adjustable bracket which is clamped to the cavitation plate of the lower unit of an outboard motor. This bracket also has female threading to receive the male end of the hose extending from the reservoir. There is currently no known commercial source for these devices, so it will be necessary to work with a local machinist to provide a custom fabrication.

B. Operation

The simplicity of the venturi system is that no pumps or electricity are required for its operation. The formulation flows under the force of gravity from the reservoir to the venturi bracket and out into the propwash (see Figure SOP 11.4). It is important to have these mounted so that the rotenone product is dispensed under the water surface and is directed into the propwash for mixing with the receiving waters. Typically, the venturi can be mounted to the cavitation plate on the lower unit of the outboard motor (see Figure SOP 11.5).

The flow rate from the reservoir tank is controlled by the shut-off valve. The applicator can adjust the flow rate so that the reservoir will be dispensed over a pre-determined period of time by considering the speed of travel and the total distance traveled while dispensing the contents of the reservoir. On a small lake, the path of the boat may be a back and forth pattern from one shoreline to another working along the long-axis of the lake. For a round lake, the path may be increasingly smaller concentric circles beginning at the lake margin and working toward the center. On large lakes, it is typical to divide the lake surface into treatment zones, with boats assigned to individual zones. These zones can be identified as actual topographic coordinates and a boat can stay within their zone with the use of a GPS receiver.

FIGURE SOP 11.1. Checking the emission rate from a drip can using a measuring cup and a stop watch.

FIGURE SOP 11.2. Masterflex peristaltic pump set up in secondary containment, personal protective equipment on hand, stop watch and graduated cylinder.

FIGURE SOP 11.3. Control Company peristaltic pump placed on rotenone bucket showing dispensing tube into stream. A 9-V battery sits alongside the pump.

FIGURE SOP 11.4. Set-up of reservoir and venturi on small boat.

FIGURE SOP 11.5. Close-up view of venturi attached to cavitation plate and tightened down using wing screws for quick installation/removal.

Appendix A
Design and Construction of Drip Cans

Design A

1. Principle—A hose attached at one end to an orifice of a reservoir (which is sealed but vented per the Marriott bottle principle) and at the other end has a spigot for controlling drip rate. Once the spigot is adjusted to provide the desired drip rate, the constant vacuum in the sealed reservoir provides for constant drip regardless of quantity of material in the reservoir. This system allows for endless dispensing rates. The construction is described below.

2. Materials:

   - ¼ inch copper tubing (approximately five feet)
   - ¼ inch (inside diameter) × 3/8 inch (outside diameter) vinyl tubing (5–10 feet)
   - ¼ inch compression brass needle valve (Lincoln Products #127410, Industry, CA 91740)
   - 5-gallon tin square can with screw cap (Freund Containers #1953, Chicago, IL 60620)
   - (2) 7/32 inch × 5/8 inch stainless steel clamps
   - Size 11 black rubber stopper with two predrilled holes

3. Procedure:

   A. Put stopper in can opening for measurements.

   B. Cut 2 pieces of ¼ inch copper tubing to length. Piece A should be ½ inch above bottom of can to two inches above the stopper (about 16 inches). Piece B should be 1 inch above bottom of the can to one inch above the stopper (about 14½ inches).

   C. Insert copper tubing into stopper holes so that Piece A is 2 inches above top of stopper and Piece B is 1 inch above top of stopper. Make sure that bottom of Piece B is about ½ inch above bottom of Piece A (see Appendix Figure 1).

   D. Use one of the stainless steel clamps to clamp the vinyl tubing onto Piece A above the stopper.

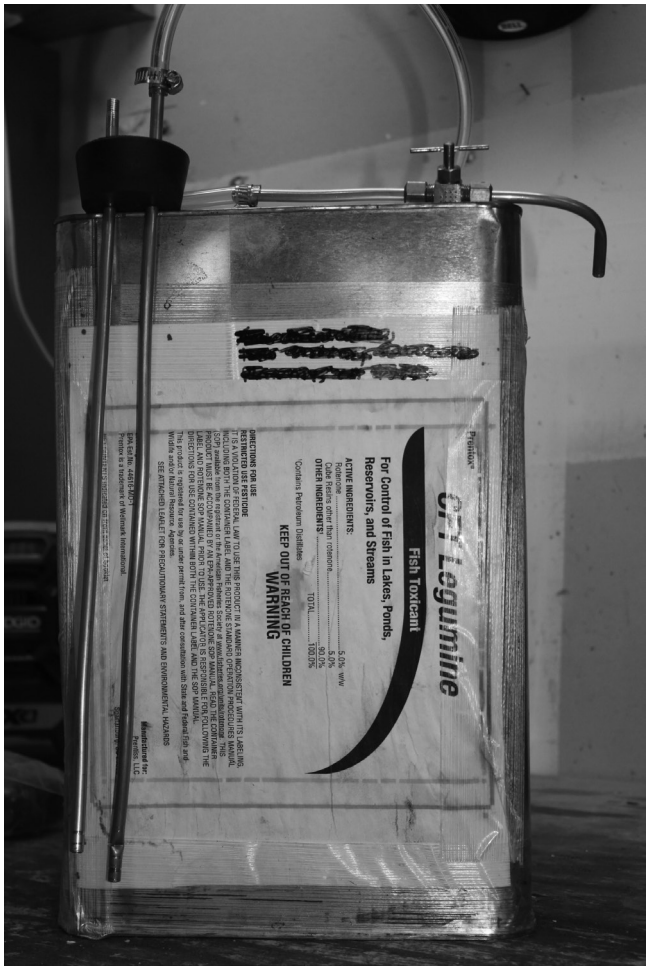
   E. Cut two, 4 inch long pieces of ¼ inch copper tubing. Attach the pieces into either end of the brass needle valve using the compression fittings.

   F. To one end of the needle valve, attach the other end of the vinyl tubing using the other stainless steel clamp. Note: The length of the vinyl tubing between the can and the valve is solely dependent on the reach between the can and the application site required for the treatment. Bend the other end of the copper tubing to function as a spout.

   G. To get the drip can working (see Appendix Figure 2):

      1. Fill the drip can with fluid.
      2. Insert the stopper into top of can.
      3. Open needle valve all of the way.

4. With finger over Piece B above the stopper, turn can on its side until fluid runs freely through the valve to the spout.
5. Turn can upright, take finger off of Piece B, and calibrate flow using needle value.
6. Make sure that the can is placed high enough above application site to provide adequate head for the entire treatment, the more head the better.
7. It may take several minutes for the flow to stabilize after adjustment.



Appendix Figure 1. Drip can as service container showing placement of copper tubes in rubber stopper and needle valve attached to longer copper tube by Tygon tubing.

Appendix Figure 2. An operating drip can.

Design B

1. Principle—A reservoir (5-gallon bucket with lid) feeds rotenone through a hose (see Appendix Figure 3) to a smaller reservoir which uses a float system (as in a toilet) to control head (see Appendix Figure 4). A hole is drilled in the bottom of this smaller reservoir to provide the desired drip rate. Drip rate can be changed with this apparatus by drilling a new hole or adjusting the operation of the float that changes the depth of fluid in the bowl enough to affect the head pressure and slow down or speed up the drip rate. This float system is described below.

2. Materials:

    - 5-gallon bucket with lid, available at any hardware store
    - Hull fitting, ¾ inch L (Cabela's Item # IE-012946)
    - Garden hose male thread
    - Cut-off valve
    - Cone filter
    - 6 inch funnel
    - 1 Red Devil, 1-gallon nylon bag strainer
    - Farnam Automatic Dog Waterer (Pet Vet Supply 1-800-283-2353), which includes 3-foot segment of ½ inch garden hose with female/male threaded ends and female receptor to connect hose to watering bowl
    - Hose clamp
    - #9 cap thread gasket
    - PVC couplings (1½ inch clean-out with threaded plug and 1½ inch adapter)

Appendix Figure 3. Drip bucket reservoir showing hull fitting, ½ inch hose with clamps, cut-off valve, and garden hose attachment.

Appendix Figure 4. Dog watering bowl reservoir and float in operation. Feeder garden hose from drip bucket reservoir on right side of photo.

3. Procedure:

   A. With circle bit (i.e., key hole saw), cut 1½ inch hole in center of lid and affix PVC couplings (no cement needed).

   B. With circle bit, cut 1 inch hole in bottom of bucket.

   C. Attach hull fitting with #9 cap thread gasket on inside of bucket.

   D. Attach about 4 inches of ½ inch garden hose to the hull fitting and tighten with hose clamp.

   E. Attach a male thread fitting to the other end of the 4 inch piece of hose.

   F. Attach cut-off valve to male thread.

   G. Insert cone filter into female receptor on dog watering bowl, then attach female end of garden hose into cut-off valve and male end into dog watering bowl.

   H. Drill hole in the floor of the dog watering bowl (near the outside edge) to provide for correct drip rate. A hole diameter of 0.059 inch (#53 drill bit) drips at a rate of 63 ml/min.

   I. To fill reservoir with clean water, unscrew clean-out and insert funnel into lid. Close cut-off valve. Pour water into funnel, covering the opening with the nylon bag strainer to keep out debris.

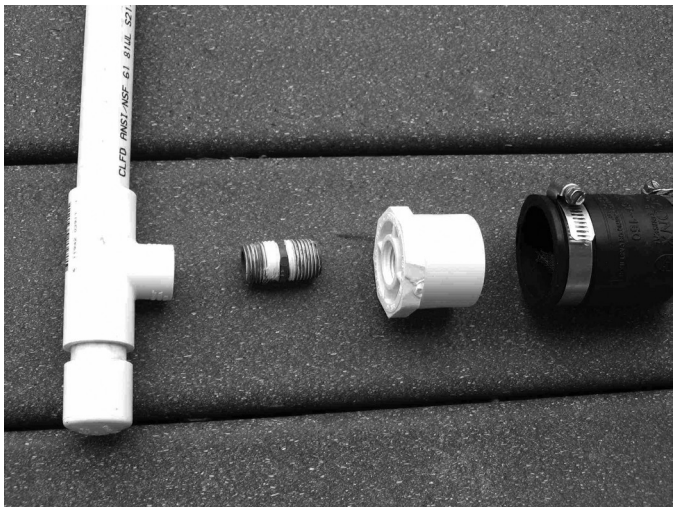
   J. To operate, open cut-off valve and allow dog watering bowl to fill until flow is shut off by rising float. Constant head will then be maintained and flow rate will be constant. Use one end of a paperclip to periodically ensure hole is clear and dripping properly.

Design C

1. Principle—a reservoir utilizing the Marriott bottle principle but the pressure-equalizing vent is attached directly to the orifice and there is no spigot (see Appendix Figures 5 and 6). With this system, the drip rate is determined by the size of a hole drilled into the slip cap covering of the T-shaped vent. Drip rate with this system can only be changed by drilling a new hole. This T-vent system is described below.

2. Materials:

   - Coleman® 5-gallon water jug
   - 2–6 inch metal hose clamps
   - Size 0 rubber stopper
   - Pipeconx® (Uniseal®) flex coupling (1½ inch diameter × 3½ inch in length).
   - PVC reducing bushing (½ inch × 1½ inch)
   - PVC tee (¾ inch × ¾ inch × ½ inch (threaded))
   - PVC slip cap (¾ inch)
   - PVC pipe (¾ inch), cut two pieces, 8 inch and 2 inch in length
   - PVC nipple (½ inch × 1½ inch length, outside thread on both ends)
   - PVC primer and cement
   - Teflon tape
   - 2- scrub pads (4 inch × 5¾ inch)



Appendix Figure 5. Reducing bushing and nipple for standpipe.

Appendix Figure 6. Completed drip can.

3. Procedure:

   A. Remove threaded water spout and air hole cover on new Coleman 5-gallon jug.

   B. Place Pipeconx flex coupling over water spout opening and rubber stopper in air hole.

   C. Glue 8 inch and 2 inch pieces of PVC pipe into either end of PVC tee.

   D. Glue cap over 2 inch piece of PVC and drill hole in cap. A #53 drill bit should yield a hole which flows at 75 ml/min.

   E. Screw ½ inch threaded nipple into short end of tee, using Teflon tape.

   F. Screw other end of ½ inch nipple into 1½ inch × ½ inch reducing bushing, using Teflon tape for good seal.

   G. Insert 1½ inch × ½ inch reducing bushing into flex coupling. Tighten hose clamps.

   H. Glue scour pads to underside of 5-gallon jug to prevent slippage while in operation.

   I. To operate.

      a. Fill reservoir with appropriate mix of clean water and rotenone formulation.

      b. Insert T-vent system over opening of jug and tighten hose clamp.

      c. Tip jug on its side with T-vent positioned vertically (Appendix Figure 6) and mixture should begin to flow immediately.

      d. It will take a few minutes for drip rate to equilibrate as a result of vacuum building up inside jug. Once equilibrated, the sides of the jug will start to collapse slightly and an occasional “glug” can be heard as air bubbles are released within the jug.

      e. No adjustment is needed. Use one end of a paperclip to periodically clean hole and ensure it is dripping properly.

Design D

1. Principle—a 5 L flexible plastic reservoir containing undiluted product feeds into silicone tubing which drips directly into the stream. Flow rate is regulated by the vertical distance (hydraulic head) of the reservoir above the end of the tubing. In most cases, this distance will be less than 2 feet. The bag can be positioned to hang directly over the water or propped up on the bank with only the end of the tubing over the water. Once the desired drip rate is reached, the vacuum created inside the bag will keep it constant regardless of the bag volume. The slowest drip rate that can be reliably achieved with this setup is about 2 ml/minute. For treated high discharge waters or for long run times multiple bags can be used.

2. Materials:

- Labtainer BioProcess Container (5 L) with 3 ports, 2 open and 1 plugged, (Thermo Scientific, catalog # SH3071401).
- Tygon 3350 Sanitary Silicone Tubing of the following dimensions:
  3/8 inch ID x ½ inch OD x 1/16 inch wall
  ¼ inch ID x 3/8 inch OD x 1/16 inch wall
  3/16 inch ID x ¼ inch OD x 1/32 inch wall
  3/32 inch ID x 5/32 inch OD x 1/32 inch wall
- Natural polypropylene reduction couplers (Eldon James brand, available from US Plastics) of the following combinations:
  3/8 inch to ¼ inch
  ¼ inch to 3/16 inch
  3/16 inch to 3/32 inch
- Two large and one small adjustable cinch clamps, similar to US Plastics Corp. acetal tubing clamp (catalog #59199).
- To assemble: First, attach 3 inches of 3/8 inch tubing to one of the open ports of the bag. Then attach a 3/8 inch to ¼ inch reducing coupler, then 3 inches of ¼ inch tubing, then a ¼ inch to 3/16 inch reducer, then 3 inches of 3/16 inch tubing, then a 3/16 inch to 3/32 inch reducer, then 5–15 feet of 3/32 inch ID tubing.

3. Procedure:

A. Clamp off one of the open ports. Attach a small screened funnel with a short piece of 3/8 inch (ID) tubing to the open port and transfer the desired amount of rotenone to drip bag. (Appendix Figure 7).

B. Remove funnel and start rolling up the bag until most of the air is pushed out. Attach the 3/8 inch end of the tubing assembly to the open port and continue rolling the bag until all the air is removed from the bag and the tubing; clamp the end of the tubing. Removing the air is crucial tomaintaining a constant drip rate.

C. Position the bag near the creek using a rope or hanging handle opening of drip bag over branch or tree stub (Appendix Figure 8).

D. Release the clamp at the end of the tubing to start the drip.

E. Monitor flow rate using a 10 ml cylinder (measure for 30 seconds and multiply by 2). After each use, do not rinse cylinder.

F. Adjust the flow rate by raising or lowering the end of the tube. Only very small adjustments are necessary.

G. Cover the drip bag with a black plastic trash bag during operation to prevent rotenone degradation.

H. At the end of the treatment remove the tubing assembly and rinse thoroughly. Rinsing the bag does not work well in the field. Instead, close both ports of the bag to contain the remaining rotenone until you have access to a garden hose or utility sink to fully rinse the bag. Allow the bag and tubing assembly to dry completely and they can be re-used several times.

Appendix Figure 7. Photograph of plastic reservoir (Labtainer BioProcess Container) with Tygon tubing attached and accessories, including funnel, black plastic bag, nitrile gloves, 10 ml volumetric cylinder, and rope for hanging bag.

Appendix Figure 8. Drip bag in operation, with black plastic covering removed for display. Notice lack of air in bag and ports which are clamped off.

Sprayers for Applying Dilute Liquid Rotenone SOP: 12.1

PURPOSE: Provide an operating protocol for spray application of prediluted liquid rotenone for fish control

PROCEDURE:

I. Preparation

Transfer the rotenone concentrate from the original container into the service container or sprayer using the procedure outlined in SOP 10.1. Sprayers described in this SOP utilize a prediluted (recommended 1 to 2%) solution of liquid rotenone formulation from a 1 to 50-gallon tank. See SOP 8.1 for spray application of undiluted rotenone concentrate.

II. Operation

Generally for stream treatments that do not utilize drip stations, begin spray application at the most downstream portion of the treatment area and work in an upstream direction on both sides of the stream. Generally for stream treatments that utilize drip stations, follow the flow of rotenone downstream from the drip station on both sides of the stream. To mark locations that have been sprayed, use a dye such as Rhodamine WT in the dilute rotenone mixture or GPS tracking technology. The spray application occurs in concert with the drip stations (if used) dispensing rotenone (see SOP 11.1).

For lake treatments, the spray application of hard to reach areas such as weed beds, areas with submerged vegetation and standing water, or shallow water areas (e.g., <3 ft) not accessible by pumper boats occur in concert with the general application. Like streams, sprayed locations may be marked using a dye such as Rhodamine WT added to the dilute rotenone mixture or GPS tracking technology.

Keep track of the amount of rotenone applied to avoid over-treatment. The total amount of rotenone applied to the stream or lake from all applications (e.g., drip cans, rotenone mixtures, diluted or undiluted) should not exceed the quantity needed for the desired treatment rate. Ensure the entire amount of diluted liquid rotenone in sprayers is completely used in the treatment area.

III. Safety

Follow label requirements for PPE for mixers, loaders, applicators and other handlers. All must wear at the minimum 1) coveralls, over long-sleeved shirt and long pants (or waders); 2) chemical-resistant gloves; 3) chemical-resistant footwear plus socks (or waders); 4) protective eyewear; and 5) a particulate respirator (see product label and Figure SOP 12.1).

The undiluted rotenone is added to the spray tank directly from a measuring device or from a service container. If added from a service container, make sure that the container is properly labeled (see SOP 4.1). The sprayer is also considered a service and must be labeled.

Make a diluted rotenone solution by partially filling the spray tank with water first and then add the predetermined quantity of undiluted rotenone liquid to the tank, then filling the tank to the desired volume. When filled, it is recommended that the solution in the spray tank is diluted to 1–2% rotenone formulation solution. Service containers can be tripled rinsed into the spray tank while filling.

Following the application, the spray equipment should be triple rinsed using site water. Rinse water should be run through the sprayer and discharged into the treatment area. Once the rinse water has all been discharged, depressurize the hoses to prevent accidental spray of rotenone outside the treatment area (e.g., in a vehicle).

IV. Application

Two commercial types of sprayers are available for applying prediluted liquid rotenone: (1) low-pressure manually-operated backpack and battery-operated sprayers and (2) high-pressure mechanically-operated agricultural sprayers. Prediluted liquid rotenone is sprayed on backwater areas of streams and rivers, seeps, springs and hard to reach shoreline areas and weed beds of ponds and lakes.

Mix rotenone from the service container with water at the designated treatment site (see SOP 10.1).

Handle equipment in a manner that minimizes the spillage of liquid rotenone product.

Operate the hand-directed nozzle in a manner to minimize small droplets and reduce drift. This is usually accomplished by adjusting the nozzle tip. Using a large-diameter orifice on the spray nozzle, directing the spray downward, and minimizing the distance the spray travels all minimize drift.

V. Equipment

Numerous models of manually operated backpack sprayers are commercially available (see Figure SOP 12.2).

Several gasoline-powered high-pressure sprayer systems (see Figure SOP 12.3) and lower pressure battery-operated electric spray systems (see Figure SOP 12.4) are commercially available. The larger units are connected to a mixing tank and transported to location with a truck, all-terrain vehicle (ATV) or tractor (see Figure SOP 12.5). Smaller units can be used in a small boat (Figure SOP 12.6).

FIGURE SOP 12.1. Safety gear required for application of diluted rotenone spray using backpack sprayer (Photo credit: Iowa Department of Natural Resources).

FIGURE SOP 12.2. Typical manually-operated backpack sprayer. Note all service containers must have labels that identify the following: (1) name and address of the person or firm responsible for the container, (2) the identity of the pesticide in the container, and (3) the pesticide signal word (e.g., “DANGER”, “WARNING”; per SOP 4.1).

FIGURE SOP 12.3. Typical gasoline-powered high-pressure sprayer units. Note all service containers must have labels that identify the following: (1) name and address of the person or firm responsible for the container, (2) the identity of the pesticide in the container, and (3) the pesticide signal word (i.e., “DANGER”, “WARNING”; per SOP 4.1).

FIGURE SOP 12.4. Typical battery-powered electric spray unit with tank. Note all service containers must have labels that identify the following: (1) name and address of the person or firm responsible for the container, (2) the identity of the pesticide in the container, and (3) the pesticide signal word (i.e., “DANGER”, “WARNING”; per SOP 4.1).

FIGURE SOP 12.5. High-pressure sprayer is transported to site with an ATV. Spray is delivered to the site using a high-pressure hose mounted on a hose reel. Note that person carrying the hose is not wearing a particulate respirator since she is not currently spraying (Photo credit: Bill Somer, California Department of Fish and Game).

FIGURE SOP 12.6. Battery operated sprayer in a small vessel (Photo credit: Chad Jackson, Washington Department of Fish and Wildlife).

Treatment of Seeps, Springs, and Upwelling Groundwater
SOP: 13.1

PURPOSE: Provide guidance on the preparation and use of rotenone for treating sources of upwelling groundwater, close to and in the upper layer of the bottom substrate, in springs, streams and lakes, and areas with limited water circulation (e.g., dense weed beds and backwater areas)

PROCEDURE:

General considerations for treating groundwater are given below in Section I followed by three rotenone mixtures that have been used successfully for treating upwelling groundwater and areas of poor water exchange: (1) Powdered Rotenone/Gelatin/Sand Mixture (Section II); (2) CFT Legumine/Vectocarb[1] Mixture (Section III); and (3) CFT Legumine/CatSan Hygiene Litter[2] Mixture (Section IV). These mixtures will deliver rotenone over extended periods to areas that are receiving rotenone-free, upwelling groundwater thus allowing for the elimination of fish from these areas. Liquid rotenone formulations other than CFT Legumine should preform similarly with Vectocarb (Section III) and CatSan Hygiene Litter (Section IV), but these mixtures have not been tested.

I. General Considerations

A. Timing of Preparation

The powdered rotenone/gelatin/sand mixture and the CFT Legumine/Vectocarb mixture can be made off-site, stored for at least several days, and transported to the treatment area. These should be stored in airtight containers and refrigerated. However, the CFT Legumine/CatSan Hygiene Litter should be made on-site within 30 minutes of use as the particles begin to disintegrate shortly after mixing. Temporarily store all the mixtures in small service containers (e.g., 1- or 5-gallon buckets with lids).

B. Identifying Groundwater

A discussion of the interaction of groundwater and surface water is provided in SOP 16.1. Locate areas of upwelling groundwater and springs by reconnoitering stream sections or using Rhodamine WT dye. Upwelling in lakes may be determined by observing sites where winter ice melts before the rest of the lake and recording locations on charts or GPS.

[1] Vectocarb-30 OM is a product of Omya International AG, P.O. Box 355, CH-4665, Ofringen, Switzerland.
[2] CatSan Hygiene Litter (non-clumping) is a product of Mars Petcare, United Kingdom.

Thermal imagery (i.e., FLIR One) using smartphone (Android or iOS system) technology may be useful in locating areas of cooler upwelling groundwater in lakes and streams. The camera takes a normal picture and a thermographic picture using different colors and places them on top of one another, allowing for easy interpretation of the image. This technique can detect a temperature difference of 0.1 °C.

Hydrologically, surface waters and groundwaters are closely connected in the hyporheic ecotone. Salmonids in particular may hold position close to the bottom in fast flowing streams where velocities are slower and critical lower temperatures from upwelling groundwater may provide a refuge during the summer. Species of warmwater fish (i.e., Centrachrids and Ictalurids) may find refuge in the muddy bottoms of lakes during cold winter months.

C. Label Requirements

Do not exceed the maximum concentration of rotenone allowed on the label (200 ppb rotenone) taking into account the total volume of water treated in the desired time frame. Use more or less of the three mixtures to achieve higher or lower desired rotenone concentrations in the treatment area as emission rates will vary with water discharge, application rate and temperature. It is always desirable to use sentinel fish (see SOP 14.1) and/or collect water samples for rotenone analysis (see SOP 16.1) to judge success when treating with mixtures.

The storage container for the mixture is considered a service container and must have the identity of the pesticide, name and address of the person or firm responsible for the container, and the signal word (e.g., “DANGER” or “WARNING”) from the rotenone product label on the original container (see SOP 4.1). Empty containers (buckets, backpacks, plastic bags, etc.) used to carry or store the mixture should be triple-rinsed using water in the treatment area to remove any rotenone residue.

II. Powdered Rotenone/Gelatin/Sand Mixture

A. Preparation

Transfer powdered rotenone from its original container in an area free of air movement such as an enclosed laboratory or warehouse. Wear all required safety gear on the label for those in contact with the powdered rotenone, directly or through drift. If an enclosed area isn’t available, or preparing the mixture off-site is logistically not feasible, then a safe area at the treatment site away from other activities should be used. Plan the mixing when air movement is expected to be minimal, set up a work area to contain spills (e.g., blue plastic tarp with a berm), wear appropriate PPE, and prepare the mixture in small quantities (i.e., 5-gallon buckets with lids).

The mixture formula is 1 pound (0.454 kg) of powdered rotenone to 1 pound (0.454 kg) of fine-to-medium clean and dry sand to 2 ounces (0.0567 kg) of unflavored gelatin (1:1:0.125). Add sufficient water to create a dough-like consistency of the mixture.

Obtain powdered rotenone and note the percentage of rotenone (a.i.) listed on the product label for determining how to modify treatment rates. Use clean sand (washed or screened to remove organics and silt) of uniform consistency (<1mm diameter) in the mixture. Gelatin powder (unflavored) is available in the home canning section of most supermarkets.

The finished mixture should form a ball when squeezed tightly, but readily break apart over time when in constant contact with the water. To assist in keeping the mixture together in water, use a weighted fine-mesh sack that allows for water exchange but retains the material.

The mixture can be stored in 5-gallon buckets or other containers with air-tight lids to keep the mixture moist until used. Plan to use all the mixture within a few days of mixing because mold will develop in air tight containers. Storing the buckets in a cool environment (i.e., refrigerator) will keep the mixture moist without mold and help maintain toxicity.

B. Operation

Prepare small amounts (less than 10 pounds (4.536 kg) total) of the sand mixture by hand in buckets or similar containers. Mixing and dust production are eased by adding no more than 1 pound (0.454 kg) sand and 1 pound (0.454 kg) powdered rotenone to the gelatin at a time, then adding a small amount of water prior to mixing. Mix a small batch while continuing to add water until the proper consistency is obtained. Continue adding the components in small amounts until the desired quantity is mixed.

Larger amounts of the mixture can be prepared by mixing all the ingredients in a mixer to a uniform consistency and then spraying water on the turning mixture to moisten the sand and gelatin just enough to cause the powdered rotenone to adhere to the sand granules. Do not attempt mixing large quantities until proficiency has been developed in mixing smaller amounts.

Although variable, tests on this mixture at 150, 250, and 350 ppb rotenone, based on total water volume discharged for a 24-h period, resulted in mean rotenone concentrations of 20, 50, and 80 ppb rotenone at 12 h post application.

On average, one cup (approximately 1 pound (0.454 kg)) of this mixture will treat an area, approximately 0.5 ft^3/s (0.0142 m^3/s) of moving water at approximately 18 ppb rotenone for up to 12 hours when using a 5% rotenone powder.

C. Safety

All mixers and applicators coming in contact with the powder formulation must wear at a minimum the following PPE: (1) coveralls, over long-sleeved shirt and long pants, (2) chemical-resistant gloves, (3) chemical-resistant footwear plus socks, (4) protective eyewear, (5) a chemical-resistant apron, and (6) a NIOSH approved particulate respirator with any R or P filter with NIOSH approval prefix TC-84A or a NIOSH approved powered air purifying respirator with HE filter with NIOSH

approval prefix TX-21C, Waterproof waders may be worn in place of coveralls, chemical-resistant apron, and chemical-resistant footwear. Only apply moistened rotenone powder/gelatin/sand mixture, and do not apply dried out mixture.

D. Application

Applicators dispense the mixture by hand over seep and upwelling areas, springs, deep beaver ponds and dense weed beds. In springs with a significant discharge, placing the mixture in a burlap bag weighted down by a rock may keep the rotenone in place during the treatment.

Do not exceed the maximum concentration of rotenone allowed on the powdered rotenone label (200 ppb rotenone) taking into account the total volume of water treated over the desired time frame.

III. CFT Legumine/Vectocarb 30-OM Mixture

A. Preparation

Plan the mixing area to contain spills (e.g., blue plastic tarp with a berm), wear appropriate PPE, and prepare the mixture in small quantities (i.e., 5-gallon buckets with lids). The mixture formula is 1 L (≈300 g) of Vectocarb to 1 L of CFT Legumine formulation (1:1 as v:v), and the resulting slurry has a consistency of cream. Use this mixture for treatment of larger areas (>2 m^2); for smaller treatment areas use the CatSan Hygiene Litter/CFT Legumine Mixture (see Section IV below) or the Powdered Rotenone/Gelatin/Sand mixture (see Section II above). Make and store this slurry in a suitable container (i.e., 1- or 5-gallon bucket with a lid).

The slurry is applied as a spray at a 1:10 ratio with site water using a small gasoline pump and a 1-inch diameter hose or standard ¾-inch garden hose. Wear all safety gear required for a spray application including gloves, safety glasses, coveralls, and respirator as required on the CFT Legumine label. Application should not result in a water concentration >200 ppb rotenone taking into account the total volume of water treated over the desired time frame.

Vectocarb 30-OM is manufactured by Omya International AG, Switzerland. Vectocarb is a fine powder of hydroxyapatite-modified $CaCO_3$ that has excellent porosity (27 m^2/g surface area), sedimentation and carrier behavior in aquatic systems; it is sold in 12.5 kg bags. Vectocarb can be obtained from Corvus Repellents, Inc., P.O. Box 336277, Greeley, CO 80633 (phone (970) 376-5473).

B. Operation

The slurry can be prepared and is stable for at least several days prior to application provided it is kept cool and out of sunlight. Do not make more slurry than you intend to use. Apply as a fine coating over the bottom of the groundwater intrusion area.

Although variable depending on groundwater discharge, temperature, and application rate, tests on this slurry demonstrate that it will emit rotenone at a relatively constant decreasing concentration of 168 ppb rotenone (at 30 minutes post)

to 20 ppb rotenone (at 3 hours post) when applying 2 L of the slurry evenly to an area of 5 m^2 (5 to 15 cm deep) with a discharge of 0.060 m^3/s. The slurry follows the discharge pattern downstream when applied to the water surface and sinks onto the streambed providing excellent coverage of the upwelling groundwater area; the highest rotenone concentrations will be at the downstream extent of the application.

C. Safety

All mixers and applicators coming in contact with the liquid formulation must wear at a minimum the following PPE: (1) coveralls over long-sleeved shirt and long pants, (2) chemical-resistant gloves, (3) chemical-resistant footwear plus socks, (4) protective eyewear, (5) a chemical-resistant apron, and (6) a dust/mist respirator. Waterproof waders may be worn in place of coveralls, chemical-resistant apron, and chemical-resistant footwear.

D. Application

Applicators dispense the slurry mixture over the groundwater site as a thin coating at a 1:10 ratio with water from the application site using a semi-closed application system (see SOP 8.1). A portable gasoline-powered water pump (Figure SOP 13.1) provides a venturi that will vacuum the slurry mixture into the water stream being discharged from the pump head over seeps, springs, and groundwater upwelling areas (Figure SOP 13.2). Avoid sucking sand and other small granular material into the pump as damage will occur; pump components may be made of plastic and aluminum.

Do not exceed the maximum concentration of rotenone allowed on the CFT Legumine label (200 ppb rotenone) taking into account the total volume of water treated over the desired time frame.

IV. CFT Legumine/CatSan Hygiene Litter Mixture

A. Preparation

Plan the mixing area to contain spills (e.g., blue plastic tarp with a berm), wear appropriate PPE, and prepare the mixture in small quantities i.e., 5-gallon buckets with lids). This preparation is made on-site, immediately prior to application. Use this mixture for spot treatment of small areas (<2 m^2); for larger treatment areas use the Vectocarb/CFT Legumine slurry (see Section III above). Both the CatSan Hygiene Litter and the CFT Legumine formulation are transported to the application site and mixed immediately prior to application in a large bucket or similar service container (Figure SOP 13.3).

CatSan Hygiene Litter is a mixture of quartz sand and chalk (calcite). Other commercially available cat litter products (e.g., Ultra Pearls Micro Crystal Cat Litter and Litter Pearls Crystal Clear Cat Litter) made of sand-like silica gel crystals, a naturally occurring mineral made of water, sand and oxygen, are likely to work too, but have not been tested. Conversely, other cat litter products that utilize natural clay likely won't work as clay has a tendency to adsorb and deactivate rotenone (see Chapter 1.4). If made immediately prior to application, the granules remain

separated and good coverage by broadcast application is possible. If this mixture is not used within an hour, it has a tendency to turn into a sticky, cooked oatmeal consistency preventing good broadcast application. Wear all safety gear required for a spray application including long gloves, safety glasses, and coveralls required on the CFT Legumine label. Application should not result in a water concentration >200 ppb rotenone taking into account the total volume of water treated over the desired time frame.

The mixture formula is 1 L of CatSan Hygiene Litter (non-clumping) to 100 ml of CFT Legumine formulation (10:1). Pour the CFT Legumine slowly into the CatSan Hygiene Litter while stirring the CatSan to ensure complete and even mixing.

CatSan Hygiene Litter (non-clumping) is manufactured by Mars Petcare, United Kingdom. It, as well as other cat litter products, can be obtained from eBay, Amazon, and pet supply distributors.

B. Operation

The granule mixture should be prepared immediately prior to application, preferably on-site. Do not make more of the mixture than intended immediate use as it does not keep well for over an hour. Broadcast the granules by hand (Figure SOP 13.4) or by using a broadcast applicator (e.g., Scotts Easy Hand-Held Broadcast Applicator).

Although variable depending on groundwater discharge, temperature, and application rate, tests on this slurry demonstrate that it will emit rotenone at a relatively constant decreasing concentration of 84 ppb rotenone (at 30 minutes post) to 13 ppb rotenone (at 3 hours post) when applying 2 L of the mixture evenly to an area of 5 m^2 (5 to 15 cm deep) with a discharge of 0.060 m^3/s. The highest rotenone concentrations will be at the downstream extent of the application.

C. Safety

All mixers and applicators coming in contact with the liquid formulation must wear at a minimum the following PPE: (1) coveralls over long-sleeved shirt and long pants, (2) elbow length chemical-resistant gloves, (3) chemical-resistant footwear plus socks, (4) protective eyewear, (5) a chemical-resistant apron, and (6) a dust/mist respirator. Waterproof waders may be worn in place of coveralls, chemical-resistant apron, and chemical-resistant footwear.

D. Application

Broadcast the granule mixture by hand or by using a hand-held broadcast applicator to seeps, upwelling areas, springs, deep beaver ponds, and dense weed beds where it is difficult to treat using other application techniques. The granules will immediately sink over the area it is applied. If the substrate consists of very soft mud the granules might sink into the mud and become inactivated. In this case, the CFT Legumine/Vectocarb mixture may be more effective.

Do not exceed the maximum concentration of rotenone allowed on the CFT Legumine label (200 ppb rotenone) taking into account the total volume of water treated over the desired time frame.

V. Additional Information

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Spateholts, R. L., and L. E. Lentsch. 2001. Utah's rotenone sandmix: a formulation to maintain fish toxicity in seeps or springs. Pages 107–118 *in* R. L. Cailteux, L. DeMong, B. J. Finlayson, W. Horton, W. McClay, R. A. Schnick, and C. Thompson, editors. Rotenone in fisheries: are the rewards worth the risks? American Fisheries Society, Trends in Fisheries Science and Management 1, Bethesda, Maryland.

Winter, T., J. Harvey, O. Franke, and W. M. Alley, 1998. Ground water and surface water a single resource. U.S. Geological Survey Circular 1139.

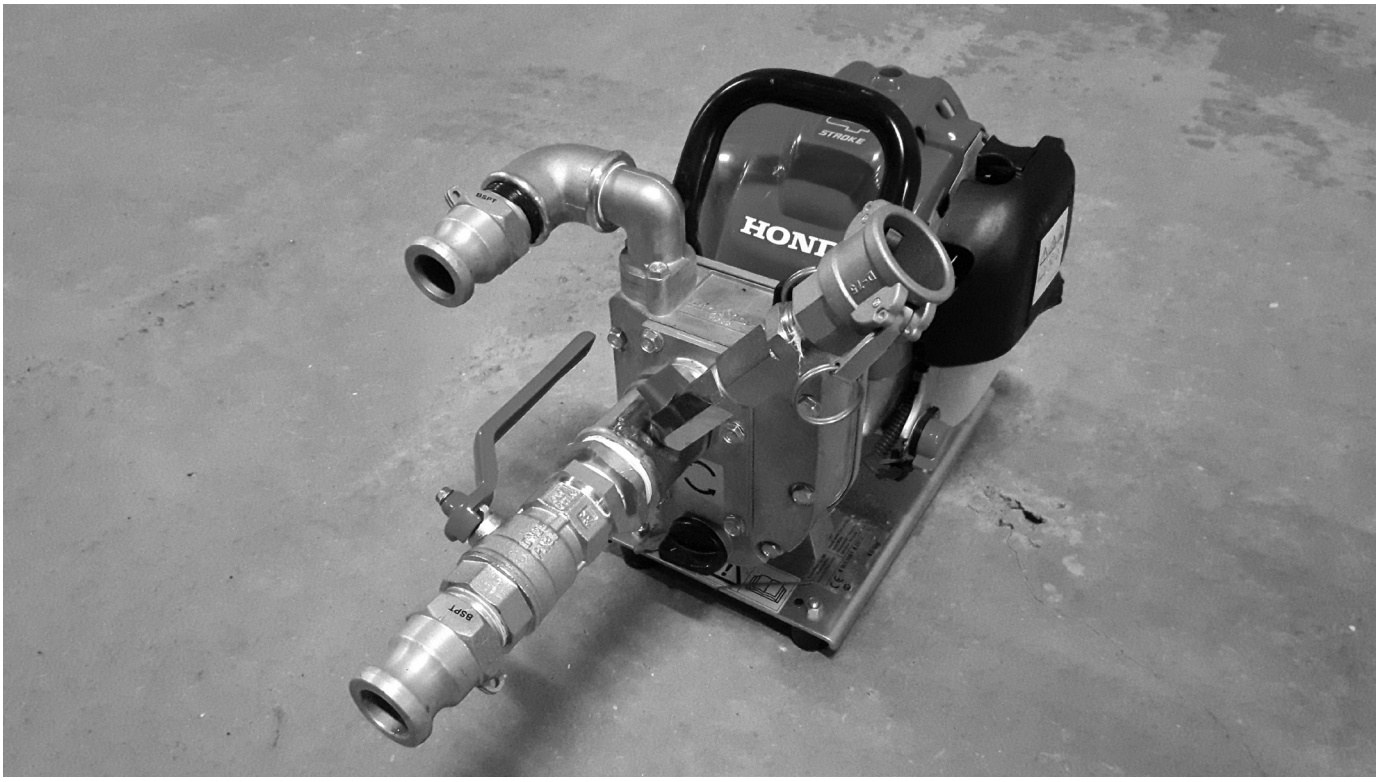

FIGURE SOP 13.1. Small portable water pump used for the application of Vectocarb/CFT Legumine slurry.

FIGURE SOP 13.2. Applying Vectocarb/CFT Legumine slurry with portable water pump and garden hose in upwelling groundwater area.

FIGURE SOP 13.3. CatSan Hygiene Litter moistened with CFT Legumine.

FIGURE SOP 13.4. CatSan Hygiene Litter/CFT Legumine mixture granules being spread by hand to upwelling groundwater area.

In-Situ Bioassays to Monitor Efficacy
SOP: 14.1

PURPOSE: Provide protocol and rationale for the use of in-situ bioassays to monitor the efficacy of rotenone treatments and potassium permanganate ($KMnO_4$) deactivation.

PROCEDURE:

I. Considerations

Both $KMnO_4$ and rotenone are toxic to fish, and both act more quickly at higher temperatures and more slowly at lower temperatures. The basis for using bioassays to monitor the effectiveness (i.e., toxicity) of $KMnO_4$ or rotenone is the concept of the dose-response relationship. The time-dependence of the toxicity of $KMnO_4$ to Rainbow Trout is shown by the Marking and Bills (1975) study in Figure SOP 14.1. As the dose (or concentration) of rotenone or $KMnO_4$ is increased, the time needed to cause an effect is decreased. Loeb and Engstrom-Heg (1971) demonstrated this concept for Brown Trout and rotenone in Figure SOP 14.2. The response is shortened with increasing dose and temperature.

Bioassays to monitor efficacy of a rotenone or $KMnO_4$ application are typically done *in-situ*, by placing fish in some enclosure (cage, bucket or net bag) within the affected waters. Cages used for this purpose typically use ¼-inch nylon mesh netting tied to a hard metal or plastic frame. Buckets are typically plastic, hold 3 to 5 gallons, have lids and ¼-inch holes drilled in the walls to allow for rapid water exchange. Net bags are typically ¼-inch mesh netting with a drawstring at one end to prevent escape of the fish. These net bags (sometimes sold as bait bags) can come with or without metal hoops to keep the void of the net open to allow fish movement. Ideally, the fish should be of a range of sizes representative of the fish species being killed during the treatment, and generally 3–5 fish are a sufficient number for each container.

Bioassays require a fish species of similar or lesser sensitivity than the target species. Note that smaller fish will likely respond faster than their larger cohorts (Brown et al. 2011). Because it is always possible that fish might escape their holding chamber, it is paramount to use holding devices in a state of good repair, provide security, and account for all fish that are used. It is preferable to use the species that the treatment is trying to eradicate. The one exception to this is when using bioassays immediately above the deactivation station to determine when deactivation can be stopped (see section II.B.1 below). In that case, the species to use is that being restocked in the water body after the treatment, assuming there is similar or lesser sensitivity to rotenone.

Another option would be to do the bioassays *ex-situ*, on-site but away from the stream margin, by placing fish of a closely-related species with similar tolerances to rotenone in a bucket with treated stream water. Replenishment of water in this bucket should be done at least hourly and artificial aeration can be provided if necessary although this may speed the breakdown of rotenone. *Ex-situ* bioassays may not provide an accurate assessment of the treatment due to different exposure conditions than that in the stream environment. One other option would be to use a sterile (triploid)

congener, where escapees would not be able to contribute genetic material to the new species being stocked into the waterbody. Sterile fish might also be the choice in situations where the intention is to manage the treated waters in a fishless state.

II. Application

A. Rotenone Treatments

1. Flowing Waters

Flowing waters are typically treated using drip stations, and a caged-fish bioassay should be conducted as far downstream as the toxic effects are expected to occur. When numerous drip stations are operated at regular intervals along the stream (1 to 2 hours travel-time apart) the cages should be placed immediately upstream of each drip station to evaluate the efficacy of the treatment from the upstream station. The death of caged fish within the duration of the treatment (typically 4–8 hours) is used to verify that the rotenone treatment is adequate and that enough rotenone carried the full distance to the next lower drip station to ensure a complete kill. On large projects where there may be many drip stations, backpack sprayers or groundwater treatments used concurrently, it may be a matter of concern whether rotenone concentrations are remaining stable, increasing or decreasing through the treatment area. If this occurs, it will be most evident at the lower end of the treatment area, and the response time of caged fish placed just above the deactivation station will allow the applicator to track any changes in the concentration of rotenone.

2. Standing Water Treatments

Evaluate efficacy at all depths throughout the water body. Suspend fish in cages or net bags at the surface, immediately off the bottom, and some mid-depth location, preferably right below the thermocline if one exists. In open water situations, wait a minimum of one day before deploying the cages to allow the chemical to mix first. Alternatively, place fish in cages in the water body the day before treatment, but recognize that variable mixing throughout the water column affects response time for the fish. After deploying the caged fish, check their status after 2 days of exposure. If the treatment is done in winter below the ice, wait a week to allow mixing before deploying the cages.

B. Deactivation Operations

Use bioassays to determine the efficacy of $KMnO_4$ in deactivating rotenone and when to terminate the deactivation. Place bioassay fish immediately upstream of $KMnO_4$ introduction site and at 15-minute and 30-minute travel time distances further downstream.

1. Upstream of Deactivation

   Place fish immediately upstream of the deactivation station after the rotenone treatment in order to determine when it is safe to cease the deactivation operation. Generally, the time to begin this bioassay is after the application of rotenone has stopped and the hypothetical clearing time for rotenone from the stream has passed. The clearing time is the travel time from the most upstream rotenone drip station or application to the deactivation station. Reintroduce fish into the cages at that time to establish they are able to survive for at least 4 hours without any signs of stress.

2. Downstream of Deactivation

   Place caged fish in, and downstream of, the mixing (contact) zone to show the efficacy of the $KMnO_4$ deactivation. Caged fish should all survive below the 30-minute contact zone and may survive at the 15-minute mark if deactivation is successful. For long deactivation operations, caged fish should be replaced daily from the stress of confinement and $KMnO_4$. If any of the fish die at the 30-minute mark, then there may be an imbalance between the concentration of $KMnO_4$ and rotenone, and the application rate of $KMnO_4$ may have to be adjusted (see SOP 7.1). As long as the residual $KMnO_4$ has been maintained, fish deaths at 30 minutes are more likely due to exposure to $KMnO_4$ than rotenone. In this situation, observations of caged fish further downstream at the 45- or 60-minute mark can be informative, because they will be exposed to less $KMnO_4$ and should be less impacted.

III. Additional Information

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Marking, L., and T. Bills. 1975. Toxicity of potassium permanganate to fish and its effectiveness in detoxifying antimycin. Transactions of the American Fisheries Society 104:579–583.

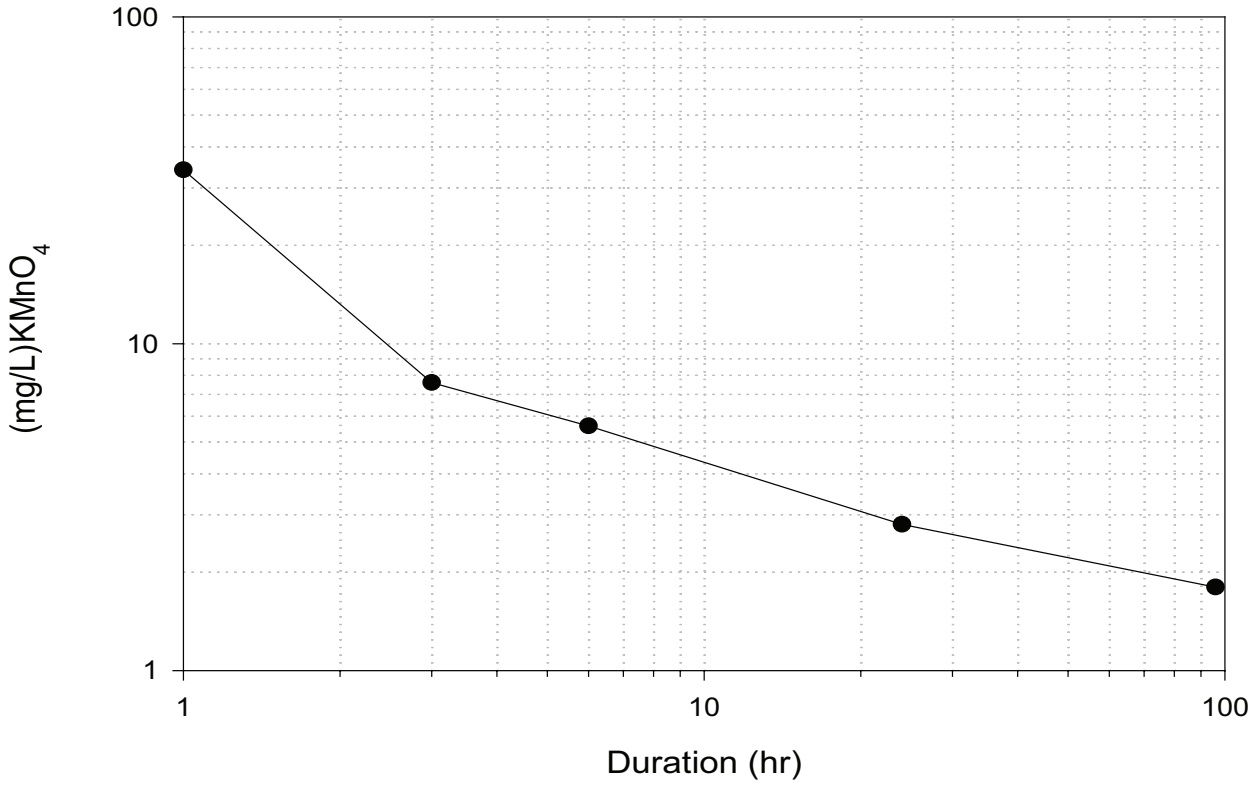

FIGURE SOP 14.1. Acute toxicity (LC_{50} values) of potassium permanganate to Rainbow Trout *Oncorhynchus mykiss* at temperature of 12°C and pH of 7.5 (Adapted from Marking and Bills 1975).

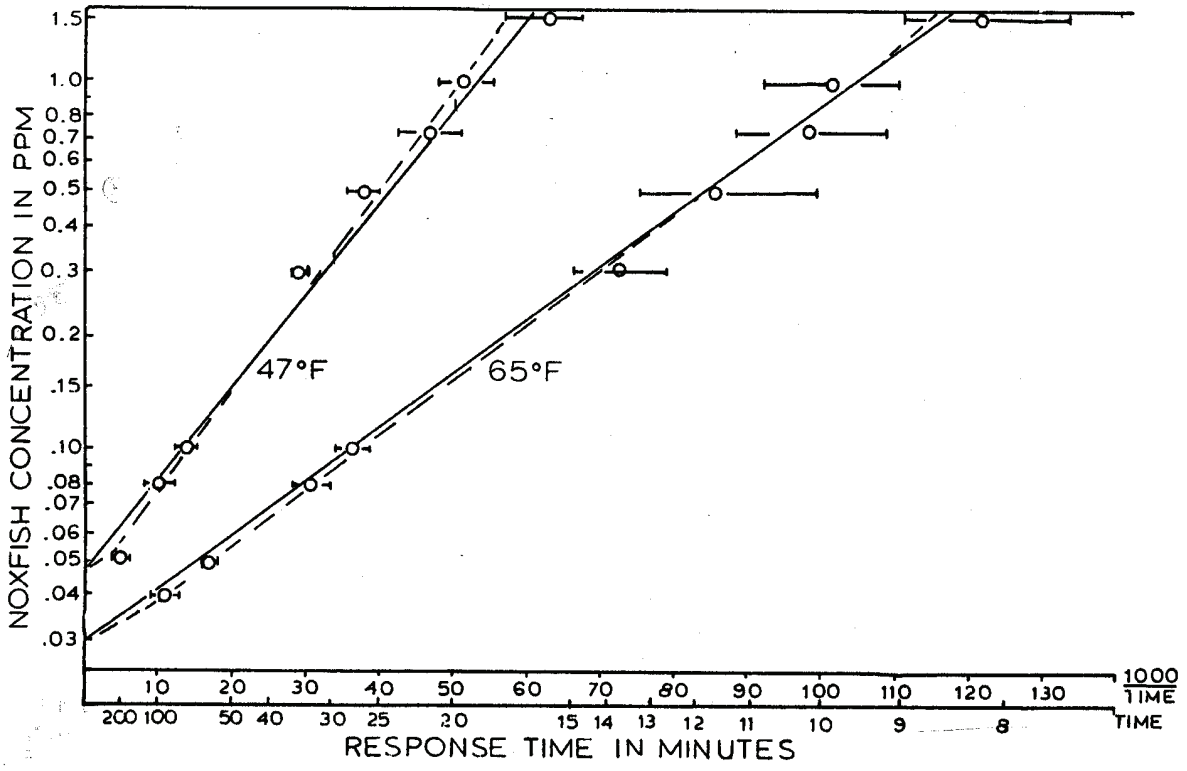

FIGURE SOP 14.2. Response time for Brown Trout *Salmo trutta* to Noxfish (Source: Loeb and Engstrom-Heg 1971).

Collection and Disposal of Dead Fish
SOP: 15.1

PURPOSE: Provide guidance for the collection and disposal of dead fish

PROCEDURE:

I. Considerations

Although not required on the label, good management of the process for collecting and disposing of dead fish reduces public relations problems and avoids the appearance of a fish kill beyond the intended treatment and project areas. The policy of the California Department of Fish and Game (1994) is to remove fish from the treatment area when dead fish may become a public nuisance or when a request is made by a public agency. The Michigan Department of Natural Resources (1993) and the Idaho Department of Fish and Game (Horton 1997) normally do not recover dead fish. The Washington Department of Fish and Wildlife normally leaves fish carcasses in the water to provide nutrients for growth of phytoplankton and zooplankton but in response to local concerns removes dead fish that have washed onto the shore of lakeside residences (Temple and Anderson 2008). All contacted state agencies reported that dead fish are recovered to avoid serious public controversy in sensitive situations. Cooperate with other agencies and entities when removing fish. Any disposal of fish or other project materials on land must be coordinated in advance with the land management agency for necessary approvals.

Plan to have adequate resources available for the collection of dead fish. Do not offer or provide dead fish for human consumption because no tolerance for rotenone in fish flesh for human consumption has been established and there are other public health issues (e.g., flies and *Salmonella*) associated with decaying flesh.

II. Collection

Collect fish during and after standing water treatments with crews in boats and/or walking the shore with dipnets. Bradbury (1986) reported that only about 30% of the dead fish could be recovered from treated lakes in Washington, depending on fish species and size, water depth and temperature, and presence of aquatic vegetation. Collect fish for two to five days after treatment depending on water temperature.

Collect fish from stream treatments using block nets. Monitor the nets and remove fish regularly. Too many fish in the nets may cause collapse of the block nets and loss of the fish downstream.

III. Metrics

It may be worthwhile to collect species identification, size (e.g., weight and length), and reproductive status metrics on the fish killed to assist in determining the carrying capacity of the stream or the lake. This information can be valuable for future fish management planning purposes.

IV. Disposal

Transport fish to a prearranged disposal site. In wilderness, fish can be buried on-site, away from the stream. Fish will likely be unearthed by bears and other carrion feeders, especially if the grave site is large or shallow. Before digging a hole for disposal, check with the responsible land use agency to determine if an archeological clearance or other approval is required. Any ground disturbance on National Forest lands requires approval from the local District Ranger, an archeological clearance and a Categorical Exclusion (NEPA) completed as part of the approval process for the treatment; factor in lead time to accomplish this approval.

Off-site, fish will usually be accepted at sanitary landfills and possibly at animal sanctuaries (e.g., zoos and wildlife parks). There may be issues with transporting a large number of dead fish including smell and animal waste on roads. Prior planning and contacting landfill operators before the treatment is prudent

V. Additional Information

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Monitoring Rotenone Concentrations in Surface and Ground Waters
SOP: 16.1

PURPOSE:

1. Mitigate exposure resulting from consuming treated fish or from drinking treated water
2. Provide guidance on the monitoring requirements and analysis of water samples for rotenone concentration
3. Recommend sampling strategies and techniques for surface water and wells

PROCEDURE:

I. Monitoring Rotenone Concentrations

Waters treated with rotenone and used for food production of aquatic species (aquaculture) require the collection and analysis of water samples for verifying that rotenone is non-detectable (<2 ppb rotenone) prior to restocking of the treated water with fish. Waters treated with >40 ppb rotenone and with drinking water intakes or with hydrologic connections to wells in the project area and/or treatment area require the user to be advised against the consumption of water until:

- Rotenone is <0.04 ppm (40 ppb) as determined by analytical chemistry, or fish of the Salmonidae or Centrarchidae families can survive for 24 hours, or
- Dilution with untreated water reduces rotenone to <0.04 ppm (40 ppb), or
- Distance or travel-time from the application site is known to reduce rotenone concentration to <0.04 ppm (40 ppb).

A. Monitoring Requirements for Aquaculture

The Certified Applicator or designee under their direct supervision must prohibit restocking of fish until monitoring samples confirm rotenone concentrations are below the level of detection (<2 ppb) for 3 consecutive samples taken no less than 4 hours apart.

1. Collection of Water Samples for Rotenone Analysis

Water samples should be collected at depth using a Kemmerer bottle or by submerging the sample bottle directly a few inches below the surface. Before taking a sample, the Kemmerer bottle is triple-rinsed with water from sampling depth.

Water samples should be collected for analysis of rotenone in chemically clean 250-ml amber glass bottles with Teflon-lined caps or other appropriate containers. Exclude air space in the sample bottles and caps.

Store samples on ice or cooled to a temperature of 4°C in the dark while in transit to and storage at the laboratory.

Laboratory-specific chain-of-custody forms should accompany samples documenting the sequence of transfer from collection to chemical analysis.

Analyze samples within the acceptable holding time of 6 days. However, others have had success with longer holding times by freezing water samples (Slabbert et al. 2014) or adding an equal amount (1:1 ratio) of acetonitrile (CH_3CN) to the water sample (Sandvik et al. 2018).

2. Analysis of Water Samples for Rotenone Concentration

Analyze samples for rotenone by liquid chromatography (LC) such as described by Dawson et al. (1983) or Sandvik et al. (2018) or by direct injection liquid chromatography/mass spectrometry (LC/MS) such as described by Vasquez et al. (2012).

Both procedures yield a minimum detection limit (MDL) of 1 ppb and reporting limit (RL) of 2 ppb.

B. Notification Requirements for Drinking Water

For applications >40 ppb or 0.04 ppm rotenone in waters with drinking water intakes or with hydrologic connections to wells, at 7 to 14 days prior to application, the Certified Applicator or designee under his/her direct supervision must provide notification to the party responsible for the public water supply or to individual private water users against the consumption of treated water until one or more of the following occurs:

- Collection of water samples for rotenone analysis (see procedure for aquaculture above) shows <40 ppb rotenone.

OR

- Bioassay of water with fish of Salmonidae or Centrarchidae families (see SOP 14.1 for detailed instructions on conducting bioassays) results in fish surviving for 24 hours as these species cannot survive rotenone concentrations >40 ppb rotenone.

OR

- Dilution with untreated water results in a rotenone concentration <40 ppb based on the calculated dilution ratio. For example: a stream discharge of 5 ft^3/s treated at 60 ppb rotenone flows into an untreated stream discharge of 15 ft^3/s. The fraction of treated to untreated water is 5 $ft^3/s \div (5\ ft^3/s + 15\ ft^3/s)$ or 0.25. The combined discharge of the two streams would have an expected concentration of 15 ppb (60 x 0.25) rotenone following dilution with untreated stream water. A demonstrated concentration <40 ppb rotenone does not require advisement against consumption.

OR

- Generally, rotenone neutralizes over distance and time so that significant residues would not be expected more than several miles or several hours travel time from the application site. Higher temperatures, solar radiation, turbulence, turbidity, and pH will increase the breakdown and dissipation of rotenone over distance and time. This would be expected to vary among water bodies and cannot be predicted with any confidence. To know with certainty, conduct a pilot test in the water body. Apply rotenone at the anticipated rate and sample rotenone in water below an application site and at multiple spots downstream. The sample site where the rotenone concentration drops below 40 ppb represents the distance or travel time needed in order to avoid the notification requirement. This distance or travel time can then be applied to any treatments in that water body at different times or locations.

II. Monitoring Recommendations

A. Surface Water

1. Lentic Environments

Generally, it is a good idea to collect several background (e.g., control) samples in the treatment area to establish the absence of rotenone in water prior to treatment. After treatment, be aware that it may take several days for rotenone to disperse throughout the waterbody and it is advisable not to collect samples for rotenone analysis until the rotenone formulation has dispersed throughout the water body.

Collect samples at various locations and depths throughout the water body paying particular attention to deep areas and other areas of potentially poor rotenone coverage or water circulation such as weed-infested shore areas. Typically, use the same locations where sentinel fish have been deployed as this will help with understanding the results.

Collecting samples every other day for the first several days followed by weekly samples thereafter until below detection (<2 ppb rotenone) is usually satisfactory to document rotenone dissipation.

Samples should be collected to comply with guidelines to prevent human contact when rotenone concentrations are >90 ppb and drinking water restrictions when rotenone concentrations are >40 ppb, if applicable (see product label).

2. Lotic Environments

Generally, it is a good idea to collect several baseline (e.g., control) samples within the treatment area and elsewhere (e.g., downstream of treatment area) to establish the absence of rotenone and other formulation ingredients in water prior to treatment.

Collect samples at various locations within the application area to determine how well rotenone is carrying between drip stations in the treatment area, especially areas where unexpected survival or mortality are occurring. Using sentinel fish locations as sampling sites may help with understanding the analytical results.

Collect samples immediately upstream of the deactivation station and at the end of the deactivation zone to establish the efficacy of the deactivation. Samples should be collected at the same location where $KMnO_4$ concentrations are monitored (see SOP 7.1). Continue collecting samples upstream and downstream of the deactivation station until it has been terminated.

3. Monitoring Reports

Examples of rotenone monitoring studies and reports can be found in Finlayson et al. (2001), Vasquez et al. (2012) and Finlayson et al. (2014).

B. Well Sampling

It is first necessary to purge the well of stagnant water because the quality of water in the casing of a well (particularly an infrequently used well) is not likely to be representative of the quality of water in the surrounding aquifer. Two methods are available, volume purging and purging by measuring field water quality parameters:

- Volume Purging—This is the removal of a predetermined volume of water from the well. Three well volumes are often considered to be the standard well volume removal amount. Based on the diameter of the well casing (typically 4 or 6 inches) and the depth of the water, calculate the volume per linear foot of casing, multiply the volume per linear foot by the height of water in the well to get an equivalent of one well volume. Then, multiply by three to get the total volume to be purged. Use the submersible pump already installed in the well, a bailer, or a portable submersible pump to purge water from the well.

- Measuring Field Water Quality Parameters—Measurement of water quality parameters serves to indicate when water removed from the well casing is representative of the aquifer. This may be done in place of volume purging, but ideally will be done concurrently. Parameters suitable for this purpose are temperature, pH, specific conductance and dissolved oxygen. When volume purging, one set of parameter readings should be taken immediately after starting the pump and again after each casing volume is purged. Field parameters are considered stabilized if consecutive measurements do not vary by more than 5 percent.

Preferably, sample water from an exterior faucet or hydrant. If not available, an inside faucet is acceptable, but in either case, the best sampling point is that which is closest to the well, and before any water storage or treatment device such as a water softener, charcoal filter or heater, which could bind to or degrade rotenone.

C. Guidance for Determining the Hydrologic Connection between Surface-Water and Wells

Under natural conditions, groundwater moves along flow paths from areas of recharge to areas of discharge at springs or along streams, lakes, and wetlands. Streams interact with groundwater in all types of landscapes and this interaction takes place in three basic ways: streams gain water from inflow of groundwater through the streambed (gaining stream), they lose water to groundwater by outflow through the streambed (losing stream), or they do both, gaining in some reaches and losing in other reaches. For groundwater to discharge into a stream channel, the altitude of the water table in the vicinity of the stream must be higher than the altitude of the stream-water surface. Conversely, for surface water to seep to groundwater, the altitude of the water table in the vicinity of the stream must be lower than the altitude of the stream-water surface. Similar interactions occur with groundwater and lakes.

The timescale for which interaction between surface water and wells can be expected to occur is highly variable. But because rotenone treatments are of such a short duration and infrequent, and because rotenone degrades so quickly and binds to organic matter (K_d values up to 194, Table 1.2), the opportunities for well contamination by rotenone are few. This is supported by Dawson (1986) who concluded that the mobility of rotenone in soil was low to slight. In addition, in spite of numerous monitoring efforts of wells in conjunction with rotenone treatments, rotenone has never been found in a well in California, Oregon (Finlayson et al. 2001; Finlayson et al. 2014), or Montana (Don Skaar, MFWP, unpublished data). Even so, there are some characteristics of hydrologic systems that can be used to judge whether there is any potential for hydrological connection between a drinking water well and treated waters, and is provided below:

- General direction of groundwater flow. Is the groundwater flowing towards or away from the surface-water body? For any well adjacent to a losing reach, the potential increases for treated surface water to flow into the nearby groundwater system and contaminate the well. Further data gathering may reveal how likely this is to occur.

- If the well draws water from the same aquifer being fed by the stream, then contamination may occur. Contamination is most likely if groundwater pumpage in the area is substantial. Contamination is less likely if the well draws from a point that is upgradient in the groundwater flow system from the treated reach.

- If the well draws from a confined aquifer at a different depth and distinct from surface water, then contamination is less likely.

- If the directional movement of groundwater in the area is not known, the measurement of specific conductivity or the composition of major ions in well water may be informative. If well water and surface water have different water chemistry, it may indicate that the movement of groundwater is from the well to the stream. Similar water chemistry may indicate that water is moving from the stream to the well.

- Aquifer conditions. What is the hydraulic conductivity of the aquifer (capacity to transmit water) and is the aquifer confined or unconfined in proximity to the affected surface-water body? A confined aquifer is bounded above and below by confining beds with little movement across the confining layer. An unconfined bed is one that surface water seeps into. Groundwater within an unconfined shallow sand and gravel aquifer with a high hydraulic conductivity are common near streams, and consequently wells may be susceptible to contamination.

- Proximity of water supply wells to the surface-water body. Withdrawing groundwater from shallow aquifers that are directly connected to surface-water bodies can have a significant effect on the movement of water between the two water bodies.

D. Methods for Investigating Hydrologic Connectivity

To determine if the stream within the treatment area is gaining or losing, conduct a "seepage run," i.e. measuring the discharge (streamflow) of the stream at numerous points throughout the treatment area. Discharges should be collected, at a minimum, above and below the point of entry of tributaries, springs and seeps, and adjacent to the location of wells. If the discharge increases in a downstream direction (accounting for surface inflows), the difference can be assumed to be due to net groundwater discharge (called a "gaining" reach). A decrease in discharge in a downstream direction can be assumed to be due to a loss of stream water to groundwater (called a "losing" reach).

If a traceable dye applied to the surface waters (as a surrogate for the application of rotenone) is not detected in the well, then contamination is less likely.

To determine if a well draws from the same aquifer fed by a stream or lake, a couple of approaches are available:

- Diel temperature variation—Surface water temperatures will fluctuate on a daily basis, and if this water is drawn into an aquifer, the magnitude of these fluctuations will be increasingly dampened as the distance and time from the surface water interface increases. Contamination is therefore less likely if no diel fluctuations are observed in the well water.

- Water chemistry differences—Specific conductivity or the composition of major ions in well water may be dissimilar to a nearby lake if the movement of groundwater is moving from the well to the lake. Water moving from the lake to the well will more likely be similar.

This information may have already been collected for the stream or lake you are treating that has wells that may be potentially affected. Contact your local, state, or federal water management agencies to gather relevant hydrogeological studies, well databases, and surface water discharge measurements necessary to evaluate the hydrologic connection between surface-water and existing wells in the treatment area/and or project area.

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