NRT Quick Reference Guide:
Organophosphorus Thion (OPT) Pesticides: Malathion, Parathion, and Methyl Parathion[1]

[1]For references please see Key References Cites/Used in National Response Team (NRT) Quick Reference Guides (QRGs) for Toxic Industrial Chemicals. QRGs are intended for Federal OSC/RPMs.

Agent Characteristics

Agent Classification: Toxic Industrial Chemical; **CAS:** 121-75-5 (malathion), 298-00-0 (methyl parathion), 56-38-2 (parathion); **Formula**: $C_{10}H_{19}O_6PS_2$ (malathion), $C_8H_{10}NO_5PS$ (methyl parathion), $C_{10}H_{14}NO_5PS$ (parathion); **Molecular Weight (g/mol):** 330.36 (malathion), 263.21 (methyl parathion), 291.26 (parathion); **Description:** OPTs represent a subset of OP pesticides which contain sulfur. The three example OPTs in this QRG have the suffix "thion" in their common name; not all OPT names include "thion." OPTs are a widely studied class of compounds which are cholinesterase inhibitors, less lethal, but with a similar mechanism of toxicity as chemical warfare agents such as GA, GB, GD, GF, and VX, described in separate QRGs. OPTs have low vapor pressure, making them difficult to maintain or disperse in air without using solvents; but have sufficient vapor pressure to require PPE. OPTs vary in their water solubility, and are also present in formulations; factors which may impact their release and decontamination. A characteristic of OPTs is that they can form toxic by-products in the presence of common decontaminants. This results from conversion of a thion sulfur group to the corresponding oxon, which is frequently equally or more toxic than the original OPT. Initial decon actions, if not properly chosen, may destroy the OPT compound, without reducing toxicity, and making subsequent decon more difficult. **Persistence:** Many OPTs degrade in the environment through hydrolysis and UV light photolysis. Hydrolysis rate is usually highly dependent on pH, resulting in persistence from hours to months. Persistence will depend upon the amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted.

Physical properties are listed at/near STP unless otherwise indicated, **and refer only to the OPT. The physical properties of formulations of the OPTs may vary substantially from those listed.**

OPT	Odor	Vapor Pressure (mm Hg)	Form, depending on purity	Water solubility (mg/L)	Melting point (ºF)/(ºC)	Flash point (ºF)/(ºC)
Malathion	Skunk like, garlic like, sulfur-like	$3.4x10^{-6}$ at 77ºF/25ºC	Clear to brown liquid	145 at 68ºF/20ºC	37/3	Above 325/163
Methyl parathion	Odorless to garlic like odor	$1.5x10^{-6}$ at 68ºF/20ºC	White crystals (solid)	55 at 68ºF/20ºC	95-97/35-36	Not available (decomposes upon heating)
Parathion	Garlic like or phenol-like	$6.68x10^{-6}$ at 68ºF/20ºC	Pale yellow to dark brown liquid	11 at 68ºF/20ºC	43/6	248-325/120-160 (depending on impurities)

Densities are all greater than 1.2 g/mL. Boiling points exceed 300 ºC. All are soluble and are formulated in a variety of common solvents.

Release Scenarios

AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED. NOTE: Malathion and parathion are semi-volatile liquids whereas methyl parathion is solid. The chemical & physical properties of solvents used may determine the characteristics of the OPT plume when released into the environment, water/water systems, or indoor facilities.
Air Release: An aerial dispersion of diluted OPT is a likely scenario and will present inhalation, skin absorption, and dermal contact hazards. OPT vapors are heavier than air, so vapors can accumulate in lower terrains. **Water/Water Systems:** OPT released into water will likely degrade within a few days; however, it could potentially persist for weeks depending on overall dilution and breakdown processes. The breakdown products of these OPT, especially oxons, may be a concern. If released into water systems such as reservoirs, treatment plants, distribution systems, public fountains or pools, treatment processes can further breakdown OPT. For water systems, plumbing, surfaces, and equipment that have contacted contaminated water must be evaluated for decon along with the bulk water. **Indoor Facility:** An aerial dispersion of diluted OPT is a likely scenario, and will present inhalation, skin absorption and dermal contact hazards. Liquid OPT will result in localized areas of surface contamination. OPT vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.

Health Effects

Onset	Symptoms and onset are dose and route dependent and may occur within hours after dermal and/or inhalation exposure from spraying. Oral ingestion either intentionally or from food contaminated with OPTs will also take several hours before onset of systemic (affects the whole body) symptoms.
Signs/ Symptoms	Regardless of route the following range of effects may occur depending on dose. **Mild:** Headache**,** dizziness**,** nausea, vomiting, abdominal cramps, diarrhea, fecal incontinence, and flu-like symptoms are common manifestations. These are generally the earliest symptoms to occur. **Moderate:** OPT poisoning can affect the whole body and can occur from all routes of exposure. In addition to mild symptoms, symptoms can also include generalized muscle weakness and twitching, slurred speech, pinpoint pupils, sweating, and shortness of breath. **Severe**: Severely poisoned patients may develop seizures, skeletal-muscle paralysis, cardiac arrhythmias, or respiratory failure, and may become comatose.
Exposure Routes	**Inhalation:** Toxic inhalation of OPT vapor is unlikely at ordinary temperatures because of its low volatility, but toxic effects can occur after inhalation. **Dermal:** Dermal exposure to OPT does not generally burn or irritate the skin, but dermal exposure produces systemic toxicity. Dermal contact is the primary route of exposure. **Ingestion:** OPTs are rapidly absorbed by ingestion resulting in acute systemic toxicity. **Other:** Certain populations (children, pregnant and nursing women, and the elderly) are potentially at higher risk. Certain genetic traits may increase susceptibility. The detection of an odor characteristic of OPT may not provide adequate warning of hazardous concentrations.

Effect Levels

Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios. Exposure guidelines are listed for **Malathion**, **Methyl Parathion, and Parathion**, respectively. For complete definitions see Key References link above. NR = not recommended.

AEGL Level in mg/m³, at exposure duration	**10 min**	**30 min**	**1 hr**	**4 hr**	**8 hr**
AEGL 1: threshold mild effects	15, NR, NR	15, NR, NR	15, NR, NR	15, NR, NR	15, NR, NR
AEGL 2: potentially irreversible effects or impaired ability to escape	150, 2.1, 2.8	150, 1.5, 1.9	120, 1.2, 1.5	77, 0.73, 0.96	50, 0.37, 0.48
AEGL 3: threshold for severe effects/medical needs/increasing potential for lethality	500, 6.4, 3.6	500, 4.4, 2.5	390, 3.5, 2.0	250, 2.2, 1.3	140, 1.1, 0.63

Exposure Guidelines: IDLH (mg/m^3) = 250, NR, 10; **NIOSH REL** (mg/m^3) skin = 10, 0.2, 0.05; **OSHA PEL** (mg/m^3) skin = 15, 0.2, 0.1; **RfD** (reference dose for lifetime oral exposure) (mg/kg/day) = 0.02, 0.00025, NR; **Oral Provisional Advisory Levels (PAL-1)** (mg/L) for general public for 1 day = 58, 0.35, 0.30 mg/L; for 30 days = 3.5, 0.35, 0.30; and for 90 days = 3.5, 0.35, and 0.30 respectively; **Soil: Industrial Exposure Scenario** (g/kg) = 13.7,0.17, 4.1; **Residential Exposure Scenario** (g/kg) = 1.22, 0.04, 3.67; **Drinking Water Health Advisory's** (mg/L) for 1 day (child) = 0.2. 0.3, NR; 10 days (child) = 0.2, 0.3, NR; Lifetime = 0.5, 0.001, NR.

Personnel Safety

Note	Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options and personnel decon may vary depending upon the agent, site, & the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: www.cdc.gov/niosh/ershdb
Medical	**Pre-incident:** A baseline cholinesterase activity determination and an annual physical and respiratory function exam. **During Incident:** Conduct periodic on-site medical monitoring, observe for any signs & symptoms as per Health Effects section above and treat accordingly as per First Aid section below.
First Aid	Immediately remove person from affected area, remove contaminated articles. Wash bare skin with warm soapy water, and rinse eyes with plain water for 10-15 minutes if exposed to liquid agent. **Antidote: Atropine sulfate, pralidoxime chloride, and 2-PAM Chloride injections (Duo Dote/Mark II kits). Antidote kit should only be administered as per pre-incident guidelines.** Send person for follow up medical attention and evaluation**.** If cleared to resume work, continue to monitor for signs/symptoms & treat accordingly.
PPE	**GENERAL INFORMATION:** NIOSH-certified Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, and protective clothing should be used. Pre-incident training and exercises on the proper use of PPE is recommended. Per NIOSH guidance - **LEVEL A:** Recommended for the initial response to an OPT pesticide incident where the exposure risks are unknown. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), and eye protection when the contaminant identity or concentration is unknown. Select Level A when the concentration is unknown or above the IDLH or AEGL-2, and when there is a potential of ocular or dermal exposure. **LEVEL B:** Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the concentration is unknown or above the IDLH or AEGL-2 and dermal exposure is less of a risk. Level B differs from Level A in that it incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not airtight. **LEVEL C:** Select Level C when the contaminant identity and concentration are known and the respiratory protection criteria factors for the use of APR or PAPR (i.e.: < IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. **LEVEL D:** Select Level D when the contaminant is known and the concentration is below the appropriate occupational exposure limit or less than AEGL-1 or other appropriate inhalation guideline (i.e.: TLV) for the stated duration times. **Note: AEGL-1 values are not available for methyl parathion and parathion**. **Downgrading PPE levels can be considered only when the identity and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring.**

Field Detection

Real-time field screening tools (results not confirmatory or quantitative): Caution should be given to equipment that has not been properly evaluated. False positive & false negatives may occur in the presence of interferents common in the environment.
NOTE: Detection equipment does not measure contaminant levels. Rather they detect the presence of an OPT pesticide at levels as low as listed below.

Minimum Screening Levels	Dräger tube - Phosphoric acid esters	CAM/ICAM/AP2C/AP4C	Misc. ACh-E inhibitor/ immuno-assay kits, i.e.: HACH - Eclox test kit; Abraxis - OP/Carbamate Test Kit*
ppm	0.05 (as Dichlorvos)	Responds to phosphorus. Possible cross sensitivity to OPTs and other OPs (concentration ranges unknown)	*1.2 ug/L malathion, not available for methyl parathion 0.8 ug/L parathion (in water)
mg/m^3	0.45 (as Dichlorvos)		

Sampling

Note: This section on sampling contains general guidelines & does not replace the need for a site-specific sampling plan (See reference list for specifics)
Sampling Concerns: Detection, sampling equipment and procedures, and analytical techniques will be highly site-specific and depend on: 1) physical state of the OPT; 2) type of surfaces contaminated (e.g., porous vs. nonporous); 3) the purpose of sampling (e.g., characterization, decon efficacy and clearance); and 4) specific laboratory requirements. Not all laboratories have the capability to determine OPT (or breakdown product, oxons) in all types of media. For sampling questions, call the EPA/HQ-EOC at 202-564-3850. **Concurrent air sampling is recommended during all sampling activities.**

Sample Locations and Planning: Initially consider atmospheric sampling to ensure worker safety and to determine if there is a vapor plume. Characterization sampling is initiated by targeted sampling and analysis to identify "hot spots," potential agent flow paths, and media or objects potentially acting as sink. Additional biased or random sampling can be used to determine the extent of potential contamination or to verify efficacy of decon. More thorough sampling (e.g., grid, statistical approach) will be required for the clearance phase, or if there are large uncertainties about the area impacted or the amount released. Because OPT are persistent chemicals, sample priorities should include surfaces that are potentially contaminated with aerosol/liquid (e.g., release site, low lying areas) and which humans are likely to contact or where vegetation is used as food.

Note: **Under specific reaction conditions breakdown products, including oxons, may form in many sample types.** Samples should be analyzed for the presence of agent & its breakdown products. To ensure sampling procedures are compatible with all analytes see analysis section below.
Types of Samples: Air: Samples are collected using appropriate solid phase absorbent (tubes) at breathing zone level (5 ft.) to assess inhalation exposure, and at ground levels (~ 6 in.) to assess off gassing at surfaces. **Water:** Water should be collected in appropriate containers with addition of appropriate preservatives. In large volumes of water, OPTs are expected to dissipate via breakdown, hydrolysis and dilution. To rule out contamination concerns, particularly in small bodies of water, analyses should include oxons. **Soil:** For localized hot spot areas where soil deposition may occur (i.e., aerosol or liquid droplets), surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Sub-surface soil samples are typically not necessary unless a large amount of liquid was poured on ground or if an underlying aquifer is endangered. **Surface Wipes:** Wipe samples are often desired to indicate absence of OPT on non-porous surfaces. **Bulk:** For hot spot areas where OPT deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces or cores of contaminated surfaces may be obtained using appropriate tools (scabbling or drills) for subsequent laboratory extraction analysis. **Other Sample Matrices:** Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.

Sample Packaging & Shipping: The packaging & shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA, & IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.

Analysis

CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes & soil). The Environmental Response Laboratory Network (ERLN) will use uniform, compatible sample prep & analytical methods. (See http://www.epa.gov/oemerln1/). For access to the nearest ERLN lab specially trained and equipped for in OPT analysis, contact the EPA/HQ-EOC at 202-564-3850.

Decontamination/Cleanup

Facilities/Material Decon/Cleanup Planning: Once site controls are in place, develop a site specific decon/cleanup plan. Decontamination may require a "tiered approach" of a variety of techniques and products. Call the EPA/HQ-EOC at 202-564-3850 for more information. **General Considerations:** A cost vs. benefit evaluation should be undertaken for each decon strategy and approach which considers: public safety, total cost, impact on the facility, wastes generated, as well as the time the facility or item will be out of service and any socio-economic, psychological, and/or security impacts that may result. Large volumes of decon wastes may be generated which will need to be collected, treated and disposed of properly. Waste handling and disposal must be addressed as early in the decontamination and cleanup process as possible (see Waste Management section below).
Disposal Option: The urgency to restore a facility as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be resistant to decon formulations, or may be cheaper to discard and replace than to decon and restore. **Monitored Natural Attenuation:** OPTs degrade slowly via natural processes. Environmental monitoring must be maintained during decon and recovery phases. Monitored natural attenuation may require institutional controls (e.g. access restriction and contaminant containment measures). The time to achieve clearance must be considered in the overall cost/benefit evaluation. This option is more passive than other options but is non-destructive to materials. The potential formation of equal or more toxic oxons from OPTs by oxidation in air must be considered. **Fix-in-Place Option:** The contaminated area may be resistant to decontamination products or may be unable or impractical to be treated. Physical barriers can be used to separate and immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution. **Decon Strategy:** A decon strategy can be developed by designating contaminated areas into 3 broad categories: 1) surfaces or "hotspots," 2) large volumetric spaces, and 3) sensitive equipment or items. Areas in each category may be treated using one or more unique decon processes in a tiered approach to the overall site specific decon strategy. Decontamination processes described here are based on expected reaction chemistry confirmed during decontamination of organophosphate chemical warfare agents.
CAUTION: OPT oxons are more toxic than the original chemical. For decon info, contact the EPA/HQ-EOC at 202-564-3850. It is advisable to choose a decon solution containing a strong oxidant, such as chlorine or peroxide, which will help prevent oxon formation. Surfaces/Hot Spots: This category is for areas smaller in size but with higher levels of agent contamination. They may require more rigorous decontamination products and methods. 1) Hypochlorite Solutions: Hypochlorite can be very damaging (corrosive) to certain surfaces and materials, and should be rinsed thoroughly afterwards. Household bleach (5.0% sodium hypochlorite) is expected to be effective for OPTs; diluted bleach may result in oxon formation. Calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas. 2) Aqueous peroxide solutions may be effective in breaking down OPTs. **Large Volumetric Spaces:** This category is for areas larger in size but with lower levels of agent contamination. 1) Monitored Natural Attenuation is more passive than other decon options and is non-destructive to materials. This option may be preferable given the scope and severity of contamination. 2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low concentration of OPT in large volumetric spaces or open areas; efficacy typically can be achieved with less waste and adverse impacts to materials. 3) Fumigation with modified vaporous hydrogen peroxide (mVHP) may be effective against OPT. HVAC systems in large indoor spaces may require a separate decon strategy, which could include the use of hot air ventilation or fumigation.
Sensitive Equipment and Items: 1) Forced or Hot Air ventilation may be used for OPT and can be used either in-situ or ex-situ to decon these items. The low volatility of all three OPTs may necessitate high operating temperatures. 2) mVHP fumigation can be used on these items with less corrosion to electronics than dilute hypochlorite solutions.
Cautions: Decon products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use (e.g., bleach results in chlorine vapors). Strong oxidizers, such as hypochlorite, may react violently with organics. Proprietary decon products such as Ultra Kleen , DF-200 , and SDF have been shown to be effective against some of the OPTs on the order of minutes to hours, but not all have been officially endorsed or tested. Formulations should be chosen that do not allow the formation of oxons. Availability, cost, and the need for specialized equipment may limit their use early in the response. Dirt, grime, and other coatings can reduce the efficacy of decon; pre-cleaning surfaces with soap and water may be needed before the application of decon formulations **but resulting pre-cleaning rinsates may contain and spread OPTs and toxic byproducts. Verification of Decon:** Site & situation specific. Please contact ERT (732-321-6600) and/or CBRN CMAT (513-487-2420) for further assistance.

Waste Management

CAUTION: Hazardous waste transportation & disposal are regulated federally; however, more stringent regulations may exist under state authority. These regulations differ from state-to-state. Detailed state regulations can be found at www.envcap.org.

Waste Management Planning: The U.S. EPA considers a waste to be hazardous: (1) if it exhibits the characteristics of ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24; (2) if it is specifically listed as a hazardous process waste (§261.21 and §261.32); or (3) if it is listed as a commercial chemical product that is discarded or spilled (§261.33). Under the Resource Conservation and Recovery Act (RCRA), U.S. EPA has specifically listed many chemical wastes as hazardous. Methyl parathion and parathion are listed hazardous wastes as P071 and P089, respectively, malathion is not a listed waste (§261.32). Requirements for transporting hazardous materials, & procedure for exemption, are specified in http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm#hmp. The U.S. EPA has developed a web-based Incident Waste Management Planning & Response Tool which contains links to guidance related to waste transportation, contact information for potential treatment, disposal facilities, & state regulatory offices, packaging guidance to minimize risk to workers, & guidance to minimize the potential for contaminating the treatment or disposal facility. Access to the EPA's web based disposal tool requires pre-registration (http://www2.ergweb.com/bdrtool/login.asp). Current resources on packaging, labeling, and shipping are available at http://www.phmsa.dot.gov/hazmat