



## ORGANOPHOSPHORUS PESTICIDES

FORMULA: Table 1      MW: Table 1      CAS: Table 1      RTI

METHOD: 5600, Issue 1      EVALUATION: FULL      Iss

OSHA : Table 2      PROPERTIES: Table 3  
NIOSH: Table 2  
ACGIH: Table 2

SYNONYMS: Table 4

SAMPLING		MEASUREMENTS	
<b>SAMPLER:</b>	FILTER/SOLID SORBENT TUBE (OVS-2 tube: 13-mm quartz filter; XAD-2, 270 mg/140 mg)	<b>TECHNIQUE:</b>	GC, FLAME PHO DETECTION (FPI)
<b>FLOW RATE:</b>	0.2 to 1 L/min	<b>ANALYTE:</b>	organophosphorus
<b>VOL-MIN:</b>	12 L	<b>EXTRACTION:</b>	2-mL 90% toluene solution
<b>-MAX:</b>	240 L; 60 L (Malathion, Ronnel)	<b>INJECTION VOLUME:</b>	1-2 µL
<b>SHIPMENT:</b>	cap both ends of tube	<b>TEMPERATURE</b>	
<b>SAMPLE STABILITY:</b>	at least 10 days at 25 °C at least 30 days at 0 °C	<b>-INJECTION:</b>	240 °C
<b>BLANKS:</b>	2 to 10 field blanks per set	<b>-DETECTOR:</b>	180 °C to 215 °C (recommendation) Table 6
		<b>-COLUMN:</b>	Table 6
ACCURACY		<b>CARRIER GAS:</b>	He at 15 psi (104
<b>RANGE STUDIED:</b>	Table 5, Column A	<b>COLUMN:</b>	fused silica capillary
<b>ACCURACY:</b>	Table 5, Column B	<b>DETECTOR:</b>	FPD (phosphorus)
<b>BIAS:</b>	Table 5, Column C	<b>CALIBRATION:</b>	standard solution: organophosphorus toluene
<b>OVERALL PRECISION (<math>\hat{S}_r</math>):</b>	Table 5, Column D	<b>RANGE:</b>	Table 8, Column 1
		<b>ESTIMATED LOD:</b>	Table 8, Column 1
		<b>PRECISION (<math>\hat{S}_r</math>):</b>	Table 5, Column 1

**APPLICABILITY:** The working ranges are listed in Table 5. They cover a range of 1/10 to 2 times the C method also is applicable to STEL measurements using 12-L samples. This method may be applicable to the determination of other organophosphorus compounds after evaluation for desorption efficiency, sample stability, and precision and accuracy.

**INTERFERENCES:** Several organophosphates may co-elute with either target analyte or internal standard, causing integration errors. These include other pesticides (see Table 7), and the following: tributyl phosphate (plasticizer), butoxy ethyl phosphate (plasticizer used in some rubber stoppers), tricresyl phosphate (petroleum oil additive), triphenyl phosphate (plasticizer, flame-retardant, and solvent), and triphenyl phosphate (plasticizer and flame-retardant in lacquers, and roofing paper).

**OTHER METHODS:** This method may be used to replace previous organophosphorus pesticide methods for partial listings. The OVS-2 tube is similar in concept to the device of Hill and Arnold [11], but offers convenience and lower flow resistance.

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**REAGENTS:**

1. Organophosphorus analytes listed in Table 1 and (optional) triphenyl phosphate, analytical standard grade.\*
2. Toluene, pesticide analytical grade.\*
3. Acetone, ACS reagent grade or better.\*
4. Desorbing solution. Add 50 mL acetone to a 500-mL volumetric flask. Diluted to volume with toluene.  
NOTE: For optional internal standard, add 1 mL of a 5 mg/mL solution of triphenyl phosphate in toluene to 500 mL desorbing solution.
5. Organophosphorus stock solutions, 10 mg/mL. Prepare individual standard stock solutions of each pesticide of interest in 90/10 toluene/acetone (V/V). All pesticides in Table 1 were found to be soluble to at least 10 mg/mL.
6. Spiking solutions for calibration (step 9) and media fortification (steps 10, 11).  
NOTE: Spiking solutions may contain more than one analyte.
  - a. Spiking solution SS-1: Dilute the volume of stock solution indicated in column F of Table 11 to 10 mL with toluene or 90/10 toluene/acetone.
  - b. Spiking solution SS-2: Dilute 1 mL of SS-1 solution with toluene in a 10-mL volumetric flask.
7. Purified gases: Helium, hydrogen, nitrogen, dry air, and oxygen, (if required by detector).

\* See SPECIAL PRECAUTIONS

**EQUIPMENT:**

1. Sampler: glass tube, 11-m x 50 mm long, with the outer 6-mm o.d. x 25 mm long tip part of the tube contains a section of 20/60 mesh XAD equivalent held in place by quartz fiber filter and polytetrafluoroethylene (PTFE) retaining ring. The tip is separated from the back section by XAD-2 sorbent or equivalent of polyurethane foam. The tip is held in place by a long plug of polyurethane foam. The tube is available as the OVS-2 sampler. See Figure 1.  
NOTE: Some OVS-2 tubes have glass fibers, as specified in the methods (see Table 11). These tubes, however, are not suitable for the more volatile pesticides (amides, phosphorothioates, phosphor sulfoxides; see Table 11). Erratic recoveries may be encountered with these tubes.
2. Personal sampling pump, with flexible connecting tubing, polyethylene, or PTFE tubing.
3. Vials, 4-mL with PTFE-lined autosampler vials with PTFE caps.
4. Gas chromatograph, flame ionization detector with 525-nm bandpass filter, phosphorus mode, integrator (Table 6).
5. Syringes, 5-mL and 100- $\mu$ L, for making standard solutions.
6. Volumetric flasks, 500-mL, 10-mL.
7. Tweezers.
8. GC vial crimper.
9. Small ultrasonic cleaning bath.

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**SPECIAL PRECAUTIONS:** Organophosphorus compounds are highly toxic. Special care should be taken to avoid inhalation or skin contact through the wearing of gloves and suitable clothing when handling pure material [13-17]. Toluene is flammable and toxic. Acetone is highly flammable. Store all samples in a well ventilated hood.

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## Métodos Analíticos - Malation

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### SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Connect the sampler to personal sampling pump with flexible tubing. The sampler is placed vertically with the large end down, in the worker's breathing zone in such a way that it does not impede work performance. [4, 12]
3. Sample at an accurately known flowrate between 0.2 and 1 L/min for a total volume of 240 L.
4. Cap both ends of the sampler with plastic caps and pack securely for shipment.

### SAMPLE PREPARATION:

5. Remove cap from large end and remove PTFE retainer ring; transfer filter and filter section to a 4-mL vial. Transfer the short polyurethane foam plug with backing to a second 4-mL vial.
6. Add 2-mL of desorbing solvent with internal standard to each vial using a 5-mL or 2-mL pipette. Cap each vial.
7. Allow to stand 30 minutes, immerse vials approximately 1/2 inch in an ultrasonic bath for 30 minutes. Alternatively, place the vials in a shaker or tumbler for 1 hour.
8. Transfer 1 to 1.5 mL from each 4-mL vial to a clean 2-mL GC vial, cap and label.

### CALIBRATION AND QUALITY CONTROL:

9. Calibrate daily with at least six working standards covering the analytical range for individual analytes.
  - a. Add known amounts of calibration spiking solution (SS-1 or SS-2 according to Table 11) to desorbing solution in 2-mL volumetric flasks and dilute to 2 mL.  
NOTE: If an internal standard is included in the desorbing solution, the volume of desorbing solution in a volumetric flask must be concentrated with a gentle stream of nitrogen in order to accommodate the specific volumes of the spiking solutions. After adding the spiking solutions to the desorbing solution, dilute to the 2-mL mark with toluene or 90:10 toluene/acetone.
  - b. Include a calibration blank of unspiked desorbing solution.
  - c. Analyze together with field samples, field blanks, and laboratory control samples (LCS) (see sections 12 and 13).
  - d. Prepare calibration graph (peak area vs.  $\mu\text{g}$  analyte), or if internal standard is used, (peak area of analyte/peak area of IS vs.  $\mu\text{g}$  analyte).
10. Prepare Laboratory Control Samples (LCS) with each sample set, in duplicate.
  - a. Remove cap from large end of sampler tube. Apply 30  $\mu\text{L}$  of spiking solution to the face of quartz fiber filter. Cap and allow to stand for a minimum of 1 hour. These should be prepared as soon as samples arrive and should be stored until analyzed.
  - b. Include an unspiked sampler as a media blank.
  - c. Analyze along with field samples and blanks, and liquid calibration standards (see section 16).
11. When extending application of this method to other organophosphorus compounds, a minimal desorption efficiency (DE) test may be performed as follows:
  - a. Determine the NIOSH REL, OSHA PEL, or ACGIH TLV in  $\text{mg}/\text{m}^3$ .
  - b. Prepare spiking solution SS-1 (refer to Table 11, or use the following formula if specific for the calculation of the weight of analyte to add to 10 mL of desorbing solution):  
For  $\text{REL} > 1 \text{ mg}/\text{m}^3$  (assuming 12-L collection vol.), let  $W = \text{REL} \times 4 \text{ m}^3$

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- For  $REL \leq 1 \text{ mg/m}^3$  (assuming 120-L collection vol.), let  $W = REL \times 40 \text{ n}$  where  $W =$  weight (mg) of analyte to dissolve into 10 mL of desorbing solution. Let  $[SS-1] = W/10 \text{ mL}$  where  $[SS-1] =$  concentration of spiking solution. Let  $[SS-2] = [SS-1] \times 0.1$  where  $[SS-2] =$  concentration of spiking solution.
- d. Prepare three tubes at each of five levels plus three media blanks. Concentration of each level may be calculated using formulae in entry 20, part II of Table 6.
  - i. Remove plastic cap from large end of sampler, apply appropriate volume of spiking solution to face of quartz fiber filter following schedule in part I of Table 6.
  - ii. Cap and allow sampler to stand overnight.
  - e. Prepare tubes for analysis (Steps 5 through 8).
  - f. Analyze with liquid standards (Steps 12 and 13).
  - g. Prepare a graph of desorption efficiency (DE) vs.  $\mu\text{g}$  of analyte.
  - h. Acceptable desorption criteria for 6 replicates is  $>75\%$  average recovery with a standard deviation of  $<\pm 9\%$ .

**MEASUREMENT:**

12. Set gas chromatograph according to manufacturer's recommendations and conditions in Table 6 and on page 5600-1. Inject sample aliquot manually using solvent front or with autosampler. See Table 7 for retention times of selected analytes.  
NOTE: If peak area is greater than the linear range of the working standard, dilute the desorbing solution containing internal standard and reanalyze. Apply appropriate dilution factor in calculations.
13. Measure peak area of analyte and of internal standard.

**CALCULATIONS:**

14. Determine the mass in  $\mu\text{g}$  (corrected for DE) of respective analyte found in the front ( $W_f$ ) and back ( $W_b$ ) sorbent sections, and in the media blank front ( $B_f$ ) and back ( $B_b$ ) sections.  
NOTE: The filter is combined with the front section. If  $W_b > W_f/10$ , report both sections as possible sample loss.
15. Calculate concentration,  $C$ , of analyte in the air volume sampled,  $V$  (L):

$$C = \frac{(W_f + W_b - B_f - B_b)}{V}, \text{mg} / \text{m}^3.$$

**CONFIRMATION:**

16. Whenever an analyte is detected, and its identity is uncertain, confirmation may be made by analysis on a second column of different polarity. If primary analysis was performed on a non-polar or weakly polar column (DB-1 or DB-5), confirmation should be accomplished by reanalysis on a polar column (DB-1701 or DB-210). See Table 7 for approximate retention times for each column type. Fewer analytes co-elute on DB-210 than on DB-1701. If retention times are more convenient for the identification of unknown analytes, a related compound not used as the retention time reference compound, then another related compound such as tributyl phosphate, Ronnel, or triphenyl phosphate may be substituted.

**EVALUATION OF METHOD:**

This method was evaluated over the ranges specified in Table 5 at 25 °C using 240-L Sampler tubes were tested at 15% and 80% relative humidity and at 10 °C and 30 °C. test atmospheres were not generated; instead, analytes were fortified on the face of t filters. This was followed by pulling conditioned air at 1 L/min. for 4 hours. No differer performance was noted at any of these temperature/humidity combinations. Evaluati precision and stability were conducted at 30 °C and 15% relative humidity. Overall: measurement precisions, bias, accuracy, and average percent recovery after long-ter presented in Table 5. No breakthrough was detected after 12 hours of sampling at 1 sampler fortified with the equivalent of 4x the NIOSH REL. Malathion and Ronnel we x REL, Sulprofos at 1/20 x REL (See Table 5, note 4). All criteria [9] were met.

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Table 1. Formula and Registry Numbers

Compound (alphabetically)	MW <sup>(1)</sup> (Daltons)	Empirical Formula	Structural		RTECS <sup>(2)</sup>
			Formula	CAS # <sup>(2,3,4)</sup>	
1. Azinphos methy	1317.32	C <sub>10</sub> H <sub>12</sub> N <sub>2</sub> O <sub>3</sub> PS <sub>2</sub>	(CH <sub>3</sub> O) <sub>2</sub> P(=S)SCH <sub>2</sub> (C <sub>7</sub> H <sub>4</sub> N <sub>2</sub> O)		86-5C
2. Chlorpyrifos	350.58	C <sub>9</sub> H <sub>11</sub> Cl <sub>3</sub> NO <sub>3</sub> PS	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)O(C <sub>6</sub> HN)Cl <sub>3</sub>		2921-
3. Diazinon	304.34	C <sub>12</sub> H <sub>21</sub> N <sub>2</sub> O <sub>3</sub> PS	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)O(C <sub>6</sub> HN <sub>2</sub> )(CH <sub>3</sub> )CH(CH <sub>3</sub> ) <sub>2</sub>		333-4
4. Dicrotophos	237.19	C <sub>8</sub> H <sub>10</sub> NO <sub>3</sub> P	(CH <sub>3</sub> O) <sub>2</sub> P(=O)OC(CH <sub>3</sub> )=CHC(=O)N(CH <sub>3</sub> ) <sub>2</sub>		141-É
5. Disulfoton	274.39	C <sub>8</sub> H <sub>10</sub> O <sub>2</sub> PS <sub>3</sub>	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)S(CH <sub>2</sub> ) <sub>2</sub> SC <sub>2</sub> H <sub>5</sub>		298-C
6. Ethion	384.46	C <sub>9</sub> H <sub>22</sub> O <sub>2</sub> P <sub>2</sub> S <sub>4</sub>	[(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)] <sub>2</sub> CH <sub>2</sub>		563-1
7. Ethoprop	242.33	C <sub>8</sub> H <sub>10</sub> O <sub>2</sub> PS <sub>2</sub>	(C <sub>2</sub> H <sub>5</sub> S) <sub>2</sub> P(=O)OC <sub>2</sub> H <sub>5</sub>		1319-
8. Fenamiphos	303.36	C <sub>13</sub> H <sub>22</sub> NO <sub>3</sub> PS	(CH <sub>3</sub> ) <sub>2</sub> CHNHP(=O)(O)(C <sub>2</sub> H <sub>5</sub> )O(C <sub>6</sub> H <sub>5</sub> )(CH <sub>3</sub> )SCH <sub>3</sub>		2222-
9. Fonofos	246.32	C <sub>10</sub> H <sub>15</sub> OPS <sub>2</sub>	C <sub>2</sub> H <sub>5</sub> OP(C <sub>2</sub> H <sub>5</sub> )(=S)S(C <sub>6</sub> H <sub>5</sub> )		944-2
10. Malathion	330.35	C <sub>10</sub> H <sub>15</sub> O <sub>3</sub> PS <sub>2</sub>	(CH <sub>3</sub> O) <sub>2</sub> P(=S)SCH[C(=O)OC <sub>2</sub> H <sub>5</sub> ]CH <sub>2</sub> C(=O)OC <sub>2</sub> H <sub>5</sub>		
11. Methamidophos	141.12	C <sub>2</sub> H <sub>6</sub> NO <sub>2</sub> PS	CH <sub>3</sub> OP(=O)(NH <sub>2</sub> )SCH <sub>3</sub>		1026-
12. Methyl parathion	263.20	C <sub>8</sub> H <sub>10</sub> NO <sub>3</sub> PS	(CH <sub>3</sub> O) <sub>2</sub> P(=S)O(C <sub>6</sub> H <sub>4</sub> )NO <sub>2</sub>		298-C
13. Mevinphos (E)	224.15	C <sub>7</sub> H <sub>13</sub> O <sub>3</sub> P	(CH <sub>3</sub> O) <sub>2</sub> P(=O)OC(CH <sub>3</sub> )=CHC(=O)OCH <sub>3</sub>		298-C
Mevinphos (E & Z)	GQ5250000				
14. Monocrotophos (Z)	223.17	C <sub>7</sub> H <sub>14</sub> NO <sub>3</sub> P			(CH <sub>3</sub>
	919-44-8 <sup>(2)</sup>	TC4981100			
Monocrotophos (E)	TC4375000				
15. Parathion	291.26	C <sub>10</sub> H <sub>14</sub> NO <sub>3</sub> PS	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)O(C <sub>6</sub> H <sub>4</sub> )NO <sub>2</sub>		56-3E
16. Phorate	260.36	C <sub>7</sub> H <sub>17</sub> O <sub>2</sub> PS <sub>3</sub>	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)SCH <sub>2</sub> SC <sub>2</sub> H <sub>5</sub>		298-C
17. Ronnel	321.54	C <sub>8</sub> H <sub>6</sub> Cl <sub>2</sub> O <sub>3</sub> PS	(CH <sub>3</sub> O) <sub>2</sub> P(=S)O(C <sub>6</sub> H <sub>2</sub> )Cl <sub>2</sub>		299-É
18. Sulprofos	322.43	C <sub>12</sub> H <sub>19</sub> O <sub>2</sub> PS <sub>3</sub>	C <sub>2</sub> H <sub>5</sub> OP(S(C <sub>2</sub> H <sub>5</sub> ))(=S)O(C <sub>6</sub> H <sub>4</sub> )SCH <sub>3</sub>		3540-
19. Terbufos	288.42	C <sub>9</sub> H <sub>21</sub> O <sub>2</sub> PS <sub>3</sub>	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(=S)SCH <sub>2</sub> SC(CH <sub>3</sub> ) <sub>3</sub>		1307-

(1) Molecular weights calculated from the empirical formula using 1979 IUPAC Atomic Weights of the Elements.

(2) RTECS = NIOSH Registry of Toxic Effects of Chemical Substances [1].

(3) Merck Index [2].

(4) Farm Chemicals Handbook [3].



## Métodos Analíticos - Malation

Compound (alphabetically)	LD <sub>50</sub> , mg/Kg <sup>(1)</sup>	OSHA PEL <sup>(4)</sup>	NIOSH REL <sup>(5)</sup>	
		mg/m <sup>3</sup>	mg/m <sup>3</sup>	(ppm)
1. Azinphos methyl	11 f	0.2	0.2	(0.015)
2. Chlorpyrifos	145	0.2	0.2	(0.014)
3. Diazinon	250 m, 285 f	0.1	0.1	(0.008)
4. Dicrotophos	16 f, 21 m	0.25	0.25	(0.026)
5. Disulfoton	2.3 f, 6.8 m	0.1	0.1	(0.009)
6. Ethion	27 f, 65 m	0.4	0.4	(0.025)
7. Ethoprop	61.5 <sup>(2)</sup>			
8. Fenamiphos	10	0.1	0.1	(0.008)
9. Fonofos	3 f, 13 m <sup>(3)</sup>	0.1	0.1	(0.010)
10. Malathion	1000 f, 1375 m	10	10	(0.740)
11. Methamidophos	25 m, 27 f			
12. Methyl parathion	14 m, 24 f	0.2	0.2	(0.019)
13. Mevinphos	3.7 f, 6.1 m	0.1	0.1	(0.011)
14. Monocrotophos	17 m, 20 f	0.25	0.25	(0.027)
15. Parathion	3.6 f, 13 m	0.1	0.05	(0.004)
16. Phorate	1.1 f, 2.3 m	0.05	0.05	(0.005)
17. Ronnel	1250 m, 2630 f	10	10	(0.760)
18. Sulprofos	227	1	1	(0.076)
19. Terbufos	1.6-4.5 m, 9.0 f			

(1) Rat-oral; from Merck Index, unless otherwise noted, f = female, m = male [2].

(2) Farm Chemicals Handbook [3].

(3) RTECS [1].

(4) OSHA Final Rule, 1989 (unenforceable, 1992); only Malathion and Parathion had previous PELs.

(5) NIOSH Recommendations for Occupational Safety and Health [5].

(6) ACGIH [18].

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Table 3. Physical Properties<sup>(1)</sup>

Compound (alphabetically)	Liquid Density (g/mL)	MP (°C)	BP °C (mm Hg)	Vapor Pressure	
				Pascal	mm Hg
1. Azinphos methyl	1.44	73-74	unstable >200	0.00018	1.35x10 <sup>-6</sup>
2. Chlorpyrifos	none found	41-42	—	0.0025	1.87x10 <sup>-5</sup>
3. Diazinon	1.116-1.118	liquid	decomp. >120	0.019	1.4x10 <sup>-4</sup>
4. Dicrotophos	1.216	liquid	400 (760)	—	none found
5. Disulfoton	1.144	oil	—	0.024	1.8x10 <sup>-4</sup>
6. Ethion	1.220	-12 to -13	—	0.0074	5.4x10 <sup>-5</sup>
7. Ethoprop	1.094	oil	—	0.0002	1.5x10 <sup>-5</sup>
8. Fenamiphos	none found	49	—	0.047	3.5x10 <sup>-4</sup>
9. Fonofos	1.16	liquid	—	0.00012	9x10 <sup>-7</sup>
10. Malathion	1.23	2.9	156 (0.7) <sup>(6)</sup>	—	none found
11. Methamidophos	1.31	54.	—	0.005	4x10 <sup>-5</sup>
				0.04	3x10 <sup>-4</sup>
				0.0023	1.7x10 <sup>-5</sup>
12. Methyl parathion	1.358	37-38	—	0.0002	1.5x10 <sup>-5</sup>
13. Mevinphos	1.25	20.6 <sup>(4)</sup>	325 (760) <sup>(4)</sup>	0.4	3x10 <sup>-3</sup>
				0.29	2.2x10 <sup>-3</sup>
14. Monocrotophos	none found	54-55 <sup>(5)</sup>	—	0.0009	7x10 <sup>-6</sup>
15. Parathion	1.26	6	375 (760)	0.005	3.78x10 <sup>-5</sup>
		10 <sup>(8)</sup>			0.00089
16. Phorate	1.156	liquid	118-120 (2.0) <sup>(3)</sup>	0.11	8.4x10 <sup>-4</sup>
17. Ronnel	sp. gr=1.48 <sup>(2)</sup>	41	—	0.1	8.x10 <sup>-4</sup>
18. Sulprofos	1.20	liquid	210 (0.1) <sup>(6)</sup>	<0.0001	<10 <sup>-6</sup>
19. Terbufos	1.105	-29.2	—	—	none found

(1) From Merck Index, unless otherwise noted [2].

(2) NIOSH 2nd Edition Method for Ronnel, S299 [7].

(3) Farm Chemicals Handbook [3].

(4) NIOSH 3rd Edition Method 2503 for Mevinphos [8].

(5) 54-55 °C for pure material, 25-30 °C for commercial r

(6) NIOSH 3rd Edition Method 5012 (EPN, Malathion, P:

(7) OSHA Stopgap Methods (See specific analyte Metho

(8) NIOSH Pocket Guide [6].

**Table 4. Synonyms**

Compound <sup>(1)</sup> (alphabetically)	Other name <sup>(2)</sup>	CAS Name
1. Azinphos methyl	Guthion*	Phosphorodithioic acid, O,O-dimethyl S-[(4-oxo-1,2,3-b
2. Chlorpyrifos	Dursban*	Phosphorothioic acid, O,O-diethyl O-(3,5,6-trichloro-2- $\zeta$
3. Diazinon	Spectracide*	Phosphorothioic acid, O,O-diethyl O-[6-methyl-2-(1-me
4. Dicrotophos	Bidrin*	Phosphoric acid, 3-(dimethylamino)-1-methyl-3-oxo-1- $\zeta$
5. Disulfoton	Di-Syston*	Phosphoric acid, dimethyl ester, ester with cis-3-hydro
6. Ethion		Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio)eth
7. Ethoprop	Prophos*	Phosphorodithioic acid, S,S'-methylene O,O,O',O'-tetra
8. Fenamiphos	Nemacur*,Phenamiphos <sup>(1)</sup>	O,O,O',O'-Tetraethyl S,S'-methylenediphosphorodithio
9. Fonofos	Dyfonate*	Phosphorodithioic acid, O-ethyl S,S-dipropyl ester <sup>(3)</sup>
10. Malathion	Cythion*	(1-Methylethyl)phosphoramidic acid, ethyl 3-methyl-4-(
11. Methamidophos	Monitor*	Phosphoramidic acid, isopropyl-, 4-(methylthio)-m-tolyl
12. Methyl parathion	Parathion Methyl <sup>(1)</sup>	Ethyl phosphonodithioic acid, O-ethyl S-phenyl ester <sup>(3)</sup>
13. Mevinphos	Phosdrin*	Phosphonodithioic acid, ethyl-, O-ethyl S-phenyl ester <sup>(4)</sup>
14. Monocrotophos	Azodrin*	[(Dimethoxyphosphinothioyl)thio]butanedioic acid dieth
15. Parathion	Ethyl Parathion <sup>(1)</sup>	Succinic acid, mercapto-, diethyl ester, S-ester with O,
16. Phorate	Thimet*	Phosphoramidothioic acid, O,S-dimethyl ester <sup>(3)</sup>
17. Ronnel	Fenchlorphos <sup>(1)</sup>	Phosphorothioic acid, O,O-dimethyl O-(4-nitrophenyl) $\epsilon$
18. Sulprofos	Bolstar*	3-[(Dimethoxyphosphinyl)oxy]-2-butenic acid, methyl
19. Terbufos	Counter*	Crotonic acid, 3-hydroxy-, methyl ester dimethyl phosph

(1) Common name as given in Farm Chemicals Handbook [3].

(2) \* = Trade name (Trademark or Registered Name) as given in Farm Chemicals Handbook [3].

(3) Merck Index [2].

(4) RTECS [1] or alternate CAS name in Merck Index [2].

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**Table 5. Method Evaluation<sup>(1)</sup>**

Compound (alphabetically)	A. Range Studied <sup>(2)</sup>		B. Accuracy	C. Bias		D. Precision Overall, $\bar{S}_{IT}$
	mg/m <sup>3</sup>	mg/sample		Ave.	Range	
1. Azinphos methyl	0.02-0.4	0.0048-0.096	± 0.178	-0.038	(-0.120 - +0.028)	0.070
2. Chlorpyrifos	0.02-0.4	0.0048-0.096	± 0.163	-0.027	(-0.054 - +0.017)	0.068
3. Diazinon	0.01-0.2	0.0024-0.048	± 0.162	-0.032	(-0.057 - -0.005)	0.065
4. Dicrotophos	0.025-0.5	0.006-0.120	± 0.169	-0.037	(-0.102 - -0.032)	0.066
5. Disulfoton	0.01-0.2	0.0024-0.048	± 0.196	-0.064	(-0.081 - -0.032)	0.066
6. Ethion	0.04-0.8	0.0096-0.192	± 0.165	-0.029	(-0.056 - -0.003)	0.068
7. Ethoprop <sup>(3)</sup>	0.01-0.2	0.0024-0.048	± 0.157	-0.025	(-0.058 - +0.025)	0.066
8. Fenamiphos	0.01-0.2	0.0024-0.048	± 0.155	-0.029	(-0.066 - +0.002)	0.063
9. Fonofos	0.01-0.2	0.0024-0.048	± 0.168	-0.036	(-0.076 - +0.008)	0.066
10. Malathion <sup>(4)</sup>	0.025-0.5	0.006-0.120	± 0.172	-0.038	(-0.064 - -0.014)	0.067
11. Methamidophos <sup>(5)</sup>	0.02-0.4	0.0048-0.096	± 0.156	-0.018	(-0.046 - +0.011)	0.069
12. Methyl parathion	0.02-0.4	0.0048-0.096	± 0.160	-0.034	(-0.082 - +0.016)	0.063
13. Mevinphos	0.01-0.2	0.0024-0.048	± 0.176	-0.042	(-0.061 - -0.004)	0.067
14. Monocrotophos	0.025-0.5	0.006-0.120	± 0.185	-0.043	(-0.047 - -0.020)	0.071
15. Parathion	0.005-0.1	0.0012-0.024	± 0.163	-0.021	(-0.045 - +0.011)	0.071
16. Phorate	0.005-0.1	0.0012-0.024	± 0.202	-0.070	(-0.097 - -0.047)	0.066
17. Ronnel <sup>(4)</sup>	0.025-0.5	0.006-0.120	± 0.172	-0.040	(-0.076 - +0.021)	0.066
18. Sulprofos <sup>(4)</sup>	0.01-0.2	0.0024-0.048	± 0.181	-0.047	(-0.054 - -0.031)	0.067
19. Terbufos <sup>(3)</sup>	0.01-0.2	0.0024-0.048	± 0.188	-0.054	(-0.091 - -0.024)	0.067

(1) NIOSH Back-up Data Report [9]

(2) The ranges studied were 1/10 to 2x the NIOSH REL (except as noted) sampling at 1 L/min for 4 hours.

(3) No NIOSH REL or OSHA PEL available; used 0.1 mg/m<sup>3</sup>.

(4) Malathion and Ronnel were studied at 1/400 to 1/20 the NIOSH REL, Sulprofos at 1/200 to 1/10 the NIOSH REL.

(5) No NIOSH REL or OSHA PEL available; used 0.2 mg/m<sup>3</sup>.

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**Table 6. Recommended Gas Chromatographic Columns and Conditions<sup>(1)</sup>**

Parameter	Wide Bore Fused Silica Capillary Column			
Stationary Phase <sup>(2)</sup>	DB-1	DB-5	DB-1701	DB-210
Polarity	non-polar	weakly polar	mod. polar	mod. polar
Length (meters)	30	30	30	30
I.D. (millimeters)	0.32	0.32	0.32	0.32
Film thickness (mm) <sup>(3)</sup>	0.25	1.0	1.0	1.0
Injection (vol., mode) <sup>(4)(5)</sup>	1 µL, SPL	1 µL, DIR	1 µL, DIR	1 µL, DIR
Oven Temperatures				
Initial (°C)	100	125	125	125
Final (°C)	275	275	275	275
Max. Recommended (°C) <sup>(5)</sup>	325	325	280	240
Program (°C/min.)	3.0	4.0	4.0	4.0
Carrier Gas (Helium)				
Head pressure (p.s.i.)	15	15	15	15

- (1) Actual conditions may vary depending on column and analytical objectives. The above are those corresponding to the RT data in Table 7.
- (2) DB-1, 100% methyl silicone; DB-5, 5% phenyl, 95% methyl silicone; DB-1701, 14 cyanopropylphenyl, 86% methyl silicone; DB-210, 50% trifluoropropyl, 50% methyl silicone. Other phase types may also work well.
- (3) Thinner films give faster separations at lower temperatures promoting analyte stability.
- (4) Use 2-mm i.d. injection port liners for 0.5-µL injection and 4-mm i.d. injection port liners for 1-2 µL injections with 0.32-mm i.d. capillary columns.
- (5) SPL = splitless mode, initial oven temperature 5-10 °C < BP of desorption solvent; DIR = direct mode, initial oven temperature 5-10 °C > BP of desorption solvent. In both modes, split-vent off time should be 60 sec for 1-2 µL injections with 4-mm ID injection port liners, and 20-30 sec for 0.5-µL injections with 2-mm ID injection port liners. Use 2-mm ID injection port liners for 0.5-µL injection and 4-mm ID injection port liners for 1-2 µL injections with 0.32-mm i.d. capillary columns.
- (6) J & W Scientific Catalog, p. 21. [10]

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Table 7. Approximate Retention Times of Selected Organophosphorous Compounds<sup>(1)</sup>

Compound (by RT on DB-1)	Capillary Column <sup>(2)</sup>				
	DB-1		Elution T, °C <sup>(4)</sup>	DB-5	DB-
	RT min	RRT <sup>(3)</sup>		RT, min	r
1. TEPP	3.71	0.128	111	5.47	7
2. Triethylphosphorothioate	4.37	0.151	113	6.34	7
3. Methamidophos	5.12	0.177	115	7.64	13
4. Dichlorvos	5.81	0.200	117	8.24	10
5. Mevinphos	10.45	0.360	131	12.92	16
6. Ethoprop	17.15	0.592	151	19.09	21
7. Naled	17.61	0.608	153	no data	23
8. Dicrotophos	18.00	0.621	154	19.94	25
9. Monocrotophos	18.27	0.630	155	20.12	28
10. Sulfotepp	19.06	0.658	157	no data	23
11. Phorate	19.18	0.662	158	20.94	23
12. Dimethoate	19.44	0.671	158	21.84	no dat
13. Demeton-S	20.15	0.695	160	21.70	25
14. Dioxathion	21.30	0.735	164	23.04	26
15. Fonofos	22.04	0.760	166	23.57	25
16. Terbufos	22.22	0.767	168	23.80	25
17. Disulfoton	23.09	0.797	169	24.19	26
18. Diazinon	23.37	0.806	170	23.75	25
19. Methyl parathion	25.37	0.875	176	26.48	31
20. Oxydemeton methyl	26. <sup>(5)</sup>	0.90	179	no data	no dat
21. Ronnel	26.86	0.927	181	27.39	29
22. Pirimiphos methyl	28.13	0.971	184	27.90	29
23. Malathion	28.53	0.984	186	28.33	31
24. Fenthion	28.74	0.992	186	28.93	31
25. Parathion	28.98	1.000	187	29.10 <sup>(A)</sup>	33
26. Chlorpyrifos	29.11	1.004	187	29.10 <sup>(A)</sup>	30
27. Crufomate	29.64	1.023	189	29.54	34
28. Isufenphos	31.91	1.101	196	31.17	33
29. Tetrachlorvinphos	33.26	1.148	200	32.60	35
30. Fenamiphos	34.09	1.176	202	33.03	37
31. Merphos	35.19	1.214	206	no data	30
32. Fensulfothion	36.61	1.263	210	35.78	42
33. Ethion	37.88	1.307	214	36.30	39
34. Sulprofos	38.49	1.328	216	36.96	39
35. Triphenyl phosphate	40.88	1.411	223	39.06	no dat
36. EPN	42.64	1.471	228	41.06	47
37. Azinphos methyl	44.16	1.524	232	43.67	no elutio
38. Leptophos	45.12	1.557	235	43.91	47
39. Azinphos ethyl	46.55	1.606	240	46.50	47
40. Coumaphos	49.31	1.702	248	50.10	67

- (1) Actual retention times (RT) will vary with individual columns and chromatographic conditions. See chromatographic performance notes. Capillary Column conditions given in Table 6. Data from B:
- (2) Sets of co-eluting or nearly co-eluting peaks are identified by letters: (A), (B), (C), (D), (E), (F), (C
- (3) Retention times relative to Parathion.
- (4) Elution temperature (°C) for DB-1 column (see Table 6 for column conditions.) Elution temperat
- convenience in selecting approximate GC oven temperatures for isothermal analyses of single o
- analytes.
- (5) Broad, tailing peak.

Table 8. Applicable Working Range and Estimated LOD

A. B. C. D. E.

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### G.

Compound (alphabetically)	Applicable Working Range				Estimated LOD	
	Atmospheric <sup>(1)</sup> mg/m <sup>3</sup>	Atmospheric <sup>(1)</sup> ppm <sup>(3)</sup>	Sample <sup>(4)</sup> µg/sample	Instrument <sup>(6)</sup> ng on column	Instrument ng on column	Sample <sup>(4)</sup> µg/sample
1. Azinphos methyl	0.02-0.6	0.0015-0.046	2.4 to 72	1.2-36	0.06	0.12
2. Chlorpyrifos	0.02-0.6	0.0014-0.042	2.4 to 72	1.2-36	0.02	0.04
3. Diazinon	0.01-0.3	0.0008-0.024	1.2 to 36	0.6-18	0.02	0.04
4. Dicrotophos	0.025-0.75	0.0026-0.077	3.0 to 90	1.5-45	0.1	0.2
5. Disulfoton	0.01-0.3	0.0009-0.027	1.2 to 36	0.6-18	0.02	0.04
6. Ethion	0.04-1.2	0.0025-0.076	4.8 to 144	2.4-72	0.02	0.04
7. Ethoprop	0.01-0.3	0.0010-0.030	1.2 to 36	0.6-18	0.02	0.04
8. Fenamiphos	0.01-0.3	0.0008-0.024	1.2 to 36	0.6-18	0.07	0.14
9. Fonofos	0.01-0.3	0.0010-0.030	1.2 to 36	0.6-18	0.02	0.04
10. Malathion	1.0-30	0.074-2.2	12. to 360 <sup>(5)</sup>	6.-180 <sup>(5)</sup>	0.05	0.1
11. Methamidophos	0.02-0.6	0.0035-0.10	2.4 to 72	1.2-36	0.3	0.6
12. Methyl parathion	0.02-0.6	0.0019-0.056	2.4 to 72	1.2-36	0.02	0.04
13. Mevinphos	0.01-0.3	0.0011-0.033	1.2 to 36	0.6-18	0.06	0.12
14. Monocrotophos	0.025-0.75	0.0027-0.082	3.0 to 90	1.5-45	0.2	0.4
15. Parathion	0.005-0.15	0.0004-0.013	0.6 to 18	0.3-9	0.02	0.04
16. Phorate	0.005-0.15	0.0005-0.014	0.6 to 18	0.3-9	0.02	0.04
17. Ronnel	1.0-30	0.076-2.3	12. to 360 <sup>(5)</sup>	6.-180 <sup>(5)</sup>	0.02	0.04
18. Sulprofos	0.1-3.0	0.0076-0.23	12. to 360	6.-180	0.03	0.06
19. Terbufos	0.01-0.3	0.0008-0.026	1.2 to 36	0.6-18	0.02	0.04

(1) To cover range of 1/10 to 3x NIOSH REL.

(2) REL in mg/m<sup>3</sup> (Table 2) + Atmospheric LOD (Column G, Table 8).

(3) Calculated for 25 °C and 760 mm Hg (NTP).

(4) Calculated for a collection volume of 120 L (2 h @ 1 L/min, 4 h @ 0.5 L/min, or 10 h @ 0.2 L/min).

(5) Calculated for a collection volume of 12 L (12 min @ 1 L/min, 24 min @ 0.5 L/min, or 1 h @ 0.2 L/min).

(6) Desorbing sample in 2.0 mL solvent and injecting 1 µL into gas chromatograph.

(7) No REL

**Table 9. Notes on Analytical Characteristics of Organophosphorous Compounds**

<b>Compound</b> (Alphabetically)	<b>A</b> Chemical and Physical	<b>B</b> Desorption and Solution	<b>C</b> Ga Ch
1. Azinphos methyl (Guthion*)			
2. Azinphos ethyl (Guthion ethyl)			
3. Chlorpyrifos (Dursban*)			
4. Coumaphos (Co-Ral*)			
5. Crufomate (Ruelene*)	1	1,4	
6. Demeton (Systox*)	2,6	5	
7. Diazinon (Spectracide*)			
8. Dichlorvos (DDVP, Vapona*)	7		
9. Dicrotophos (Bidrin*)			
10. Dimethoate (Cygon*)	1	1,4	
11. Dioxathion (Delnav*)			
12. Disulfoton (Di-Syston*)	2		
13. EPN (Santox*)			
14. Ethion			
15. Ethoprop (Prophos*)			
16. Fenamiphos (Nemacur*)	1	1,4	
17. Fensulfothion (Dasanit*)	3	4	
18. Fenthion (Baytex*)		5	
19. Fonofos (Dyfonate*)			
20. Isofenphos (Oftanol*)	1	1	
21. Leptophos (Phosvel*)		5	
22. Malathion (Cythion*)			
23. Merphos (Folex*)	4	5	
24. Methamidophos (Monitor*)	1	1,3,4	
25. Methyl parathion (Parathion methyl)			
26. Mevinphos (Phosdrin*)	6,7		
27. Monocrotophos (Azodrin*)	1	1,2,4	
28. Naled (Dibrom*)	5	5	
29. Oxydemeton methyl (Metasystox-R)	3	1,5	
30. Parathion (Ethyl parathion)			
31. Phorate (Thimet*)	2,7		
32. Pirimiphos methyl (Actellic*)			
33. Ronnel (Fenchlorphos)			
34. Sulfotepp (TEDP)			
35. Sulprofos (Bolstar*)			
36. TEPP	7	5	
37. Terbufos (Counter*)	2		
38. Tetrachlorvinphos (Gardona*)			
39. Tributyl phosphate			
40. Triphenyl phosphate			

\* = Trade name, Registered name, or Trademark (Farm Chemicals Handbook [3]).

(1) Observations made during selection and validation of selected analytes [9]; refer to next page.



**Table 9 (Continued) - Notes on ANALYTICAL CHARACTERISTICS**

- A. CHEMICAL AND PHYSICAL**
1. Amide or phosphoramidate, some slightly acidic, very polar chemically.
  2. Alkyl thioether, easily oxidized to sulfone and sulfoxide.
  3. Sulfoxides, easily oxidized to sulfone. Also very polar chemically.
  4. Phosphite, easily air oxidized to phosphate (Merphos - DEF).
  5. Vicinal dibromide, easily debrominated (Naled - Dichlorvos).
  6. Two or more isomers commonly exist (e.g. Demeton-O and Demeton-S; cis- and trans- isomers).
  7. Relatively volatile, can be lost if media or vials are left uncapped for even a short time.
- General: Organophosphorous compounds are easily destroyed at mildly alkaline pH. Significant losses can occur for trace levels of compounds on alkaline glass surfaces. Losses can be minimized by neutralizing after washing, if alkaline detergent is used.
- B. DESORPTION AND SOLUTION**
1. Solubility of concentrated solutions in toluene enhanced by the addition of 1% methanol. Solubility in hexane very unfavorable even for dilute solutions.
  2. Changing from 100% toluene to 90/10 toluene/acetone, desorption from glass fiber filters improved from 62% to 98%, desorption from quartz fiber filters improved from 30% to 101%.
  3. Changing from glass fiber filters to quartz fiber filters, desorption in toluene improved from 88% and desorption in 90/10 toluene/acetone improved from 70% to 99%.
  4. These compounds are more chemically polar than the other listed organophosphorous compounds. Desorption from XAD-2 or from glass or quartz fiber filters in hexane was incomplete. Desorption in toluene was adequate except as noted in 2 and 3 above. The use of 10% acetone improved recoveries for all analytes to satisfactory levels.
  5. The desorption characteristics of these compounds were not evaluated.
- General:
- a. The presence of acidic hydrogen or double bonded oxygen anywhere in the molecule structure greatly decreases solubility in non-polar solvents and increases desorption from polar surfaces and sorbents.
  - b. While glass fiber filters and toluene desorbant were adequate for most preliminary tests, the method was given wider application for the method by the use of quartz fiber filters and 90/10 toluene/acetone desorbant.
  - c. Solvents with lower boiling points (e.g., methylene chloride, chloroform, diethyl ether, and ethyl acetate) had good desorption power nearing equivalent to acetone, but rendered less satisfactory gas chromatographic response. This effect may be due to better analyte mass-transfer from the injection port to the capillary column with higher boiling solvents using splitless or direct injection.
- C. GAS CHROMATOGRAPHY**
1. Poor chromatography may be encountered with dirty or undecanted columns. Clean quartz wool plugs stuffed in the injection port liner are better than silanized wool reducing losses within the injection port.
  2. Multiple, shifted, irregular, or severely tailing peaks may be observed in the chromatogram if degradation or oxidation of the analytes occur prior to injection, within the injection port or on-column.
  3. Multiple peaks may be observed due to presence of isomers.
  4. Short elution time, compound may co-elute with solvent if oven temperature is too high.
  5. Long elution time, compound may be lost if run time is too short, column or injection port is not cooled, or split-vent-valve opens too soon when injected in splitless or direct injection mode.
  6. Azinphos methyl did not elute from DB-1701 even though Azinphos ethyl did elute.
  7. Potential internal standards: Triphenyl phosphate is more favorable if multiple peaks are observed because it is less volatile and elutes in an area of the chromatogram having few other analytes.

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**Table 10. Other Methods of Analysis for Organophosphorous Compounds in Air**

<b>Document</b>	<b>Method Number</b>	<b>Organophosphorous Compound(s)</b>
Hill & Arnold <sup>(1)</sup>	Chlorpyrifos, Demeton-O, Demeton-S, Diazinon, Dimethoate, and Parathion	
NMAM, 2nd ed. <sup>(2)</sup>	v. 1 P&CAM 158 v. 5 P&CAM 295 v. 6 P&CAM 336 v. 3 S 208 v. 3 S 209 v. 3 S 210 v. 6 S 280 v. 3 S 285 v. 3 S 295 v. 6 S 296 v. 6 S 299 v. 3 S 370	Parathion Dichlorvos (DDVP) TEPP Tributyl phosphate Triortho cresyl phosphate Triphenyl phosphate Demeton EPN Parathion Mevinphos Ronnol Malathion
NMAM, 3rd ed. <sup>(3)</sup>	2503 2504 5012 5514	Mevinphos TEPP EPN, Malathion, and Parathion Demeton
OSHA <sup>(4)</sup>	62	Chlorpyrifos, Diazinon, Parathion, DDV
OSHA Stopgap <sup>(5)</sup>	Each method is separate and unnumbered. Refer to by name.	Azinphos ethyl Azinphos methyl Coumaphos Crufom ate Demeton Dicrotophos Dioxathion Disulfoton EPN Ethion Ethoprop Fenamiphos Fensulfothion Fenthion Fonofos Isofenphos Leptophos Methamidophos Methyl dematon Methyl parathion

- (1) Hill and Arnold [11]  
 (2) NMAM, 2nd ed. [7]  
 (3) NMAM, 3rd ed. [8]  
 (4) OSHA Analytical Methods Manual [12]  
 (5) OSHA Stopgap Methods [4]

**Table 11. Preparation of Spiked Media and Liquid Calibration Standards**

Spiking Levels (Fraction of REL) <sup>(1)</sup>	Spiked Concentration				
	A.	B.	C.	D.	E.
	1/30x REL	1/10x REL	1/3x REL	1x REL	3x REL
<b>I. Spiking of Media or Liquid</b>					
1. Spiking Solution to use:	SS-2	SS-2	SS-1	SS-1	SS-1
2. Preferred Syringe Size:	50 µL	50 µL	50 µL	50 µL	100 µL
3. Spiking Volume <sup>(2)</sup> to use:	10 µL	30 µL	10 µL	30 µL	90 µL
<b>II. Total µg spiked<sup>(3)</sup></b>					
1. Azinphos methyl	0.8	2.4	8	24	72
2. Chlorpyrifos	0.8	2.4	8	24	72
3. Diazinon	0.4	1.2	4	12	36
4. Dicrotophos	1.0	3	10	30	90
5. Disulfoton	0.4	1.2	4	12	36
6. Ethion	1.6	4.8	16	48	144
7. Ethoprop	0.4	1.2	4	12	36
8. Fenamiphos	0.4	1.2	4	12	36
9. Fonofos	0.4	1.2	4	12	36
10. Malathion <sup>(5)</sup>	4	12	40	120	360
11. Methamidophos	0.8	2.4	8	24	72
12. Methyl parathion	0.8	2.4	8	24	72
13. Mevinphos	0.4	1.2	4	12	36
14. Monocrotophos	1.0	3	10	30	90
15. Parathion	0.2	0.6	2	6	18
16. Phorate	0.2	0.6	2	6	18
17. Ronnel <sup>(5)</sup>	4	12	40	120	360
18. Sulprofos	4	12	40	120	360
19. Terbufos	0.4	1.2	4	12	36
20. General (for 120L) <sup>(4,5)</sup>	x/30	x/10	x/3	x	3x

(1) For a collection volume of 120 L. Range corresponds to values within column C, Table 8.

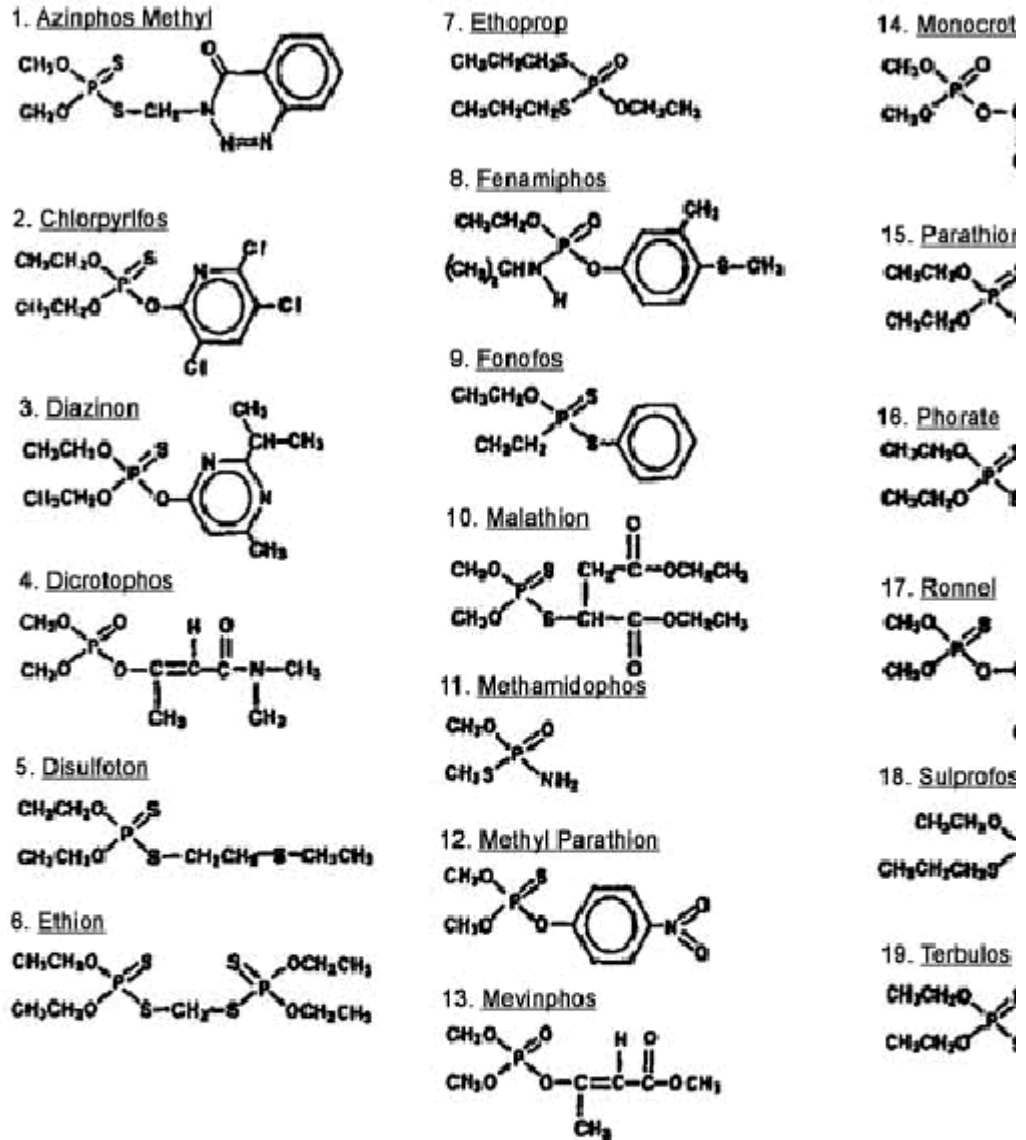
(2) For liquid calibration standard preparations, add specified volume to 2 mL desorption solution in a 20 mL desorption flask. For laboratory control samples spiked at the REL, apply volume specified in column E, in duplicate. For Desorption Efficiency determination, apply specified volume to each of five levels in triplicate.

(3) Total µg per sample, for spiked media, or per 2 mL desorption solution for liquid calibration standards.

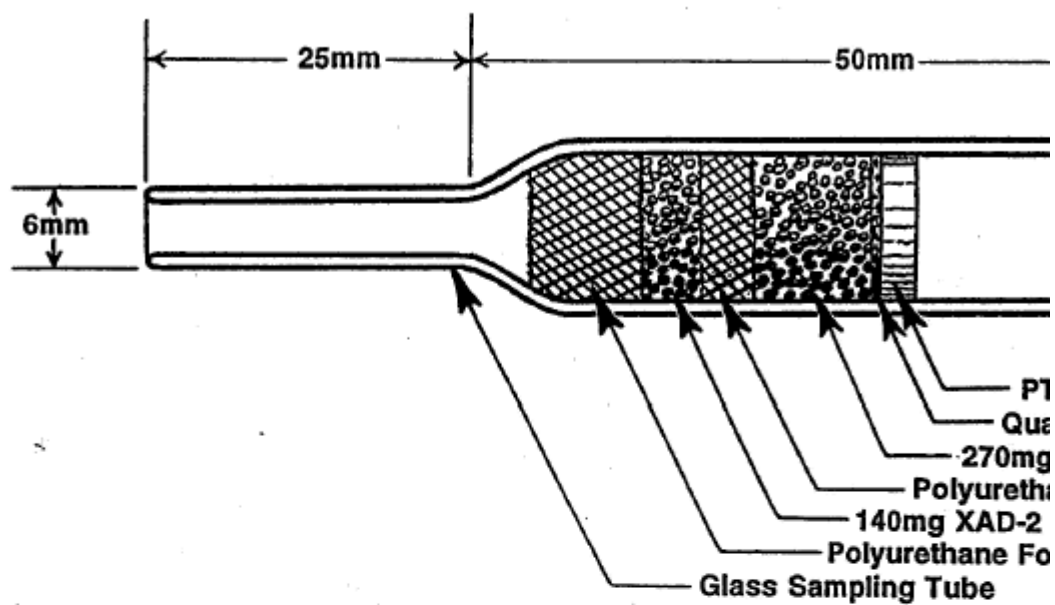
(4) Where x, µg/sample = REL, µg/L x 120 L/sample; and y, mg/mL = REL, mg/m<sup>3</sup> x 4 m<sup>3</sup>/mL.

(5) For all REL > 1 mg/m<sup>3</sup>, use 1/10 x REL in the calculations (assumes that collection volume is 12 L instead of 120 L).

Figure 1. Structure of Organophosphorus Compo







**FIGURE 2. OVS-2 SAMPLER**

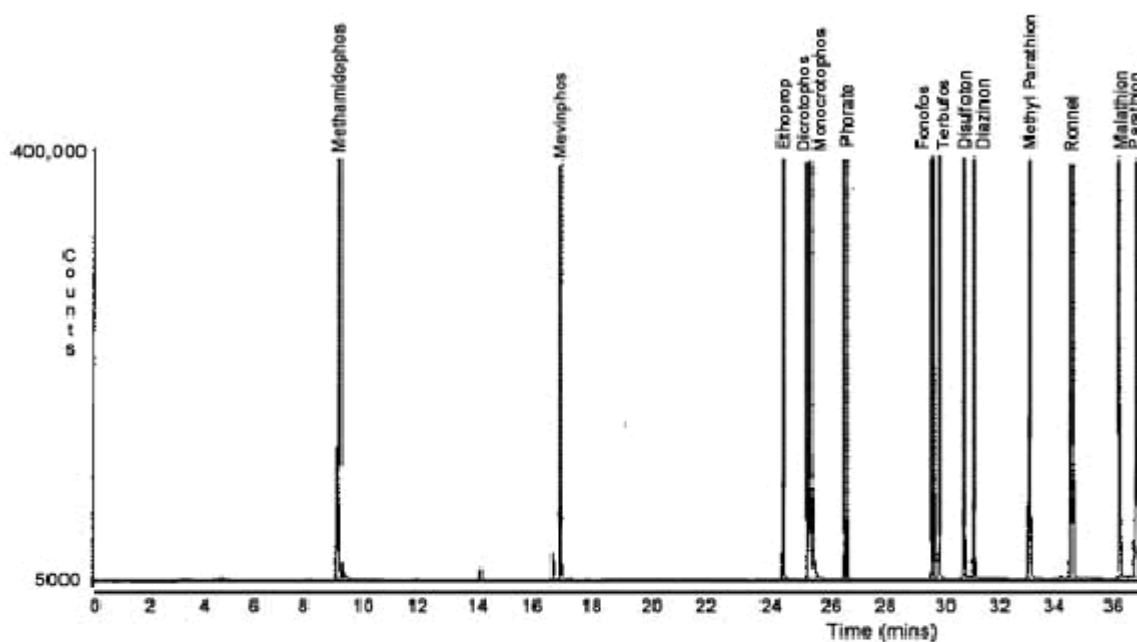


Figure 3. Typical Chromatogram of Organophosphorous Compounds

Column: DB-1 Fused Silica Capillary Column, 30 meters x 0.32 mm i.D. x 0.25 um Film Thickness  
 Temperature Program: 89 C to 275 C at 3.0 C/Minute

Concentration of Analytes: 0.6 x NIOSH REL, Except Sulprofos (0.06x), Malathion, and Ronnel (Bot)  
 1.8 ug/ml Parathion and Phorate  
 3.6 ug/ml All other compounds  
 7.2 ug/ml Azinphos Methyl, Chlorphyrifos, Methamidophos, and Methyl Parathion  
 9.0 ug/ml Dicrotophos and Monocrotophos  
 14. ug/ml Triphenyl Phosphate  
 14.4 ug/ml Ethion