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Comprehensive Review of Applicable Supercritical Fluid Extraction Research

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Introduction:

Literature pertaining to supercritical fluid extraction (SFE) is summarized in the following report. References often summarize literature reports relevant to trace environmental analytical extractions rather than applications having immediate or direct application to the Hazardous Material Response Unit (HMRU). Nonetheless, this literature defines the scope of compounds that have been the topic of SFE research. Additionally, the referenced studies often delineate optimal extraction conditions for many of the compounds mentioned. Although the applications for the HMRU may be significantly different from trace environmental studies, it is reasonable to expect SFE conditions defined in the literature will be similar to the those chosen by the HMRU team for extraction of suspect materials.

Report Organization:

The following report is organized according to the seven literature searches that yielded relevant citations. In order of appearance, these sections are 1) chemical warfare agents; 2) explosives; 3) hazardous chemicals; 4) poisons, toxins and mycotoxins; 5) toxic (lethal) chemicals and toxicants; 6) pesticides in soil; and 7) pesticides from plant and animal tissues. These sections are maintained throughout each of the three major report divisions. The last division of the report contains seven appendices that individually address each of the literature searches summarized above. Each appendix contains either the actual literature abstracts or, in the case of Appendix 7 (pesticides from plant and animal tissues), a more detailed summary of the literature references.

The three major report sections (described below) are physically separated by yellow dividers. Table 1 in the first section gives an overview of the literature search topics and number of citations obtained. This list was further divided into those references most likely to be relevant for HMRU objectives. A brief summary of each of the seven topics that yielded relevant references follows. This summary is intended to quickly orient the reader to the more detailed information the follows. The second report section consists of seven tables (Tables 2-8) that summarize the literature surveys defined in Table 1. Generally, these tables are organized with the most recent literature references listed first, although there are a few exceptions to this guideline. Chemicals or classes of compounds are made most visible by listing these in the left column to facilitate locating relevant literature citations that pertain to specific hazardous compounds. The final report section contains seven appendices (Appendices 1-7) that compile abstracts from the literature search. These abstracts usually contain detailed information regarding extraction conditions or, at the very least, give information sufficient to locate the original literature work. Abstracts appear in the same order as referenced in Tables 2-8. Each appendix is separated by a blue divider sheet to facilitate reference location.

Section I - Brief Description of Literature Search Topics

The literature searches that were conducted are summarized in Table 1. Table 1 gives both the total number of literature references obtained during the search as well as the number of literature references that are most likely relevant to the objectives of the HMRU. Seven of the categories searched yielded relevant references. Below is a more detailed description of how the literature search was performed followed by a brief summary of the highlights contained in each of the categories.

A comprehensive literature search on the application of supercritical fluid extraction (SFE) to different hazardous chemicals was performed. The Chemical Abstracts data base was searched from 1965 to the present. Literature references included open literature publications, books, patents, and dissertations (thesis). The total number of references for each of the compounds (or compound class) searched in combination with SFE is presented in Table 1. In some cases, only general categories were searched in conjunction with SFE, while in other cases specific compounds within a general category were searched. Individual compounds were searched using their Chemical Abstracts Services (CAS) identification numbers, while categories were searched by all descriptors necessary to obtain the category of information. For example, if the general category to be searched was SFE coupled with chemical warfare (CW) agent/simulants, the descriptors searched for SFE included: SFE, supercrit or supercritical and fluid and extract or extn or extraction. The descriptors searched for CW agents included: chemical or chem and warfare or the individual agents of GB, GD, HD, GA, and VX (the addition of the word "agent" or "simulant" was not necessary as both of these would be included the set searched with just CW). The literature references from each of the two categories were coupled to find references that applied to both SFE and CW agents. The total number of references pertaining to both key words are presented in Table 1. An initial screening of these abstracts narrowed the field to those citations that describe extraction of potentially relevant compounds or compound classes from a solid or liquid matrix. These abstracts are presented in the "related literature" column of Table 1. The number of literature references for the use of SFE with pesticides was over 200, so the abstracts from this category were obtained only back to 1986.

Table 1. Initial Literature Search Results of the Application of Supercritical Fluid Extraction With Hazardous Chemicals

General Category	Specific Compound	Total Number of Literature References	Related Literature References[a]
Chemical Warfare Agents/Simulants	GB, GD, HD, GA, VX	4	4
Explosive(s)		31	13
	Picric Acid	0	0
Biological Agents, Biologicals		0	0

Classical Agents	Phosgene Diphosgene Hydrogen Cyanide Cyanogen Chloride Arsine Phosgene Oxime Phenyldichloroarsine Ethyldichloroarsine Methyldichloroarsine Diphenylchloroarsine Diphenylcyanoarsine Adamsite Bromobenzylcyanide 2-Chloroacetophenone *o*-Chlorobenzylidene malononitrile 3-Quinuclidinyl benzilate	3 (with hydrogen cyanide only)	0
Hazardous Chemicals		8	2
Poisons, Toxins, Mycotoxins		15	14
Toxic (Lethal) Chemicals, Toxicants,		53	27
Pesticides from Soil[b]		76	76
Pesticides from Plant and Animal Tissue		64	29

[a] Based on a preliminary reading of abstracts

[b] References to 1986, references prior to this date were not obtained due to the large quantity (over 200).

I.1 CW Agents

CW agents are relatively non-polar compounds and are readily amenable to supercritical fluid extraction. CW compounds are, however, prone to hydrolysis and the resulting hydrolysis products tend to be too polar for efficient extraction by supercritical fluids without prior or *in situ* derivatization to decrease polarity. One study investigated the recovery of alkyl alkylphosphonofluoridates and dialky alkylphosphonates from painted surfaces [L15-1]. SFE compared favorably with organic solvents for extracting these compounds. Extraction of CW agent residues and transformation products from soils represents a more challenging analytical task. Several reports claim that higher recoveries for CW agents are obtained by SFE as compared to solvent extraction [L15-2,4]. One of these studies examined extraction of tabun, soman, sarin, dibenz[b,f] (1,4) oxazepine, and methylphosphonic acid from soil [L15-2]. A separate study reached similar conclusions by comparing soil extraction efficiencies of CW-related compounds between SFE and ultrasonic extraction with methanol [L15-4]. Higher recoveries were found for SFE of dimethylmethylphosphonate, 2-chloroethylethyl sulfide, and diisopropylmethyl-phosphonate; however, SFE had a higher recovery variability than solvent extraction. SFE extraction conditions for CW agents from soils and recoveries have recently been complied in a review article [L15-3].

I.2 Explosives

Supercritical fluid extraction techniques have been described for a variety of munitions with applications ranging from large-scale industrial processing to analytical extractions. Most of the munitions research addresses nitroaromatic and nitramine explosives [L7-3]. Due to the relatively high polarity of these compounds, SFE usually involves the use of a polar organic modifiers to enhance extraction efficiency [L7-4,11,17]. Research has been conducted on optimizing soil extraction procedures with provisions for process scale-up for soil remediation. Soil characteristics and extraction conditions have been examined in detail for TNT [L7-20]. Controversy exists in the literature regarding the suitability for SFE for simultaneous extraction of multiple munitions residues from soil . One research group determined that no single set of conditions could effectively extract a broad range of nitro aromatics from soil; thereby concluding that an existing solvent extraction protocol was superior to SFE for broad-range analytical screening [L7-15]. On the other hand, it seems conditions can be optimized to extract specific nitroaromatic residues. One study found that SFE gave comparable extraction efficiencies as solvent extraction for HMX, an explosive that has a very high degree of polarity [L7-16]. Nitroaromatic explosives rapidly become transformed in the soil to aniline derivatives.

SFE approaches have not proven effective at extracting aniline components from soil. However, SFE seems ideally suited for certain unique large-scale applications such as the recycling of off-specification munitions or removal of a specific munitions from bulk amounts of soil for remediation [L7-14,20]. Both these approaches capitalize on the ease of removing the supercritical fluid transfer media after extraction.

Trace analytical techniques are critical for detection of concealed explosive devices, for identification of post-detonation residues, and for environmental assessment and remediation efforts. SFE techniques have been incorporated as first stages in a variety of multidimensional chromatographic approaches. One group utilized SFE in combination with a thermal desorption modulator GC interface and thermal energy analysis (TEA) detection [L7-17]. Nitrate esters decomposed in the modulator; however, the system could provide fast analysis (<10 min) for stable nitro compounds on 200 mg of soil with a detection limit of 2.6 ppb for 2,4-DNT. Other investigators used a pheyl-bonded silica precolumn to preconcentrate explosives from water before SFE transfer of the preconcentrated constituents from the phenyl column to an on-line GC [L7-23]. Recoveries of explosives were 80-95% for reagent water or 52-95% for well and surface water for the analytes tested (2,3-dinitrotoluene, 2,4-dinitrotoluene and trinitrotoluene). Other research has investigated the use of SFE to extract soils, swabs, and dust at post-detonation sites [L7-22,28]. Extraction with CO_2 generally gave recoveries of >60 % with nonpolar compounds giving higher recoveries than the polar explosives. Lower recoveries were obtained from carbon-containing samples. This approach was used to verify explosive residues on post-detonation swab samples taken from a metal plate located near a test explosion.

Another study investigated multidimensional chromatographic profiling of explosives/propellants to identify source origin [L7-24]. An instrument was designed that could operate on very small samples of soil or spent firearm cartridge casings. Samples were extracted by SFE and compounds separated by SFC before detection by three on-line detectors (UV, flame ionization, and electron capture detectors). This analytical system was used for detection of explosives in soil with a detection limit for some compounds as low as 100 pg. The system was also used to obtain chemical fingerprints of propellants in spent firearm cartridge casings. The chemical profiles could be compared to identify the original propellant batch.

A unique study utilized SFE to identify the chemical species in Semtex that ECD-based security explosives detectors respond to [L7-27]. The components extracted from Semtex by SFE were characterized by off-line GC with ECD and mass-spectrometric detection. Authors concluded that the detector responds to the ethylene glycol dinitrate. ECD response to PETN, RDX or other extractable components was excluded based on either low ECD response or insufficient vapor pressure.

I.3 Hazardous Chemicals

This section only revealed two literature citations. One reference that describes the SFE of *o*-dinitrobenzene from soil using CO_2 with and without acetone or methanol modifiers [L19-1]. The second reference compares a variety of extraction methods, including SFE, for the extraction of hexachlorobutadiene and chlorobenzenes from contaminated estuarine sediments [L19-3].

I.4 Poisons, Toxins, Mycotoxins

A number of review articles exist that describe the general extraction of naturally produced toxins from food products. The toxicants of primary importance include alkaloid and mycotoxin classes [L19-1,4 and L25-5]. Of particular interest are cereal grains that have been stored under conditions that promote fungal growth. *Fusarium* molds, a ubiquitous fungi, produce a diverse range of highly toxic metabolites that contaminate grain. Some of the most important *Fusarium* mycotoxins are the trichothecenes and zearalenone. Besides being a serious treat to livestock and consumers, trichothecene class toxins are suspected as having been used as chemical warfare toxins in Southeast Asia.

The trichothecene class can be further divided into type A and B toxins. Type A toxins include, diacetoxyscirpenol (DAS), neosolaniol, HT-2, and T-2 toxins. Type B toxins consist of deoxynivalenol (DON), 3-acetyldeoxynivalenol, 15-acetyldeoxynivalenol, nivalenol, fusarenon-X. Supercritical fluid chromatography (SFC) has proven suitable of the analysis for both A and B type toxins [L19-5]. Similarly, SFE conditions have been described that can efficiently extract both classes of trichothecenes. Since these fungal metabolites are relatively polar, use of a polar modifier is necessary to promote efficient SFE extraction. One representative study used CO_2 with 5% methanol at 550 atm and 60°C to extract DON, DAS, and T-2 from cereal grains [L19-2]. Extraction efficiencies were near quantitative (85-90%) and detection limits of 250 ppb were readily achieved using LC separation combined with MS detection. A number of studies have achieved similar results for SFE extraction of trichothecenes [L19-8,9 and L25-3]. SFE extracts from grains produced with methanol-modified CO_2 contain a considerable interferrences. Further sample clean up may be desired depending on the sophistication of analyte detection. Although one study claims SFE is comparable to normal-phase or immunoaffinity cleanup for extraction of zearalenone and trichothecenes from corn [L25-1], other research groups promote the use of SFE in addition to these clean up techniques [L25-4]. A review article that specifically addresses SFE conditions for both A and B type trichothecenes from food and feedstuffs has recently appeared [L25-2].

One literature publication addresses the extraction of naturally produced algal toxins. This study examined the SFE extraction of the cyclic peptide toxins nodularin and the microcystins LR, YR, and RR from algal scum samples [L19-3]. Once extracted, the toxins were separated and quantitated by micellar electrokinetic capillary chromatography.

I.5 Toxic (lethal) Chemicals, Toxicants

Numerous references describe SFE of highly toxic polychorinated biphenyls (PCB's), dibenzo-*p*-furnans (PCDD's) and dibenzofurans (PCDF's) from soils, sediments, treated wood (utility poles, fence posts, and railfroad ties), fly ash, and paper pulp [L19-

6,18,36,41,42,47]. Typically extraction efficiencies for SFE rival or exceed those described for solvent extraction. A representive study found >92% recovery for extraction of 29 PCB's from contaminated river sediment [L19-6]. Near quantiative recoveries for representative PCB's can be obtained with relatively mild extraction conditions (40°C with 5% methanol-modifed CO_2) [L19-47].

SFE is typically applied to extract compounds from solid matricies; however, the technique can also be used to extract organic compounds from aqueous samples [L19-6,16,19,33,35]. The advantage to extracting with supercritical fluids over organic solvents is the reduction of hazardous waste that is generated and the ease of concentrating the extracted analyte. This technique has been applied to extract a wide variety of analytes from water including benzene, phenols, cresols, chlorinated ethanes, and fermentation products [L19-6,19,35]. A recent review compares liquid-liquid, liquid-solid, and SFE approaches for determining pesticides, herbicides, insecticides and fungicides in water at detection limits lower than 0.1 ppb [L19-16]. This technique has been adapted to provide semicontinuous extraction of phenols from aqueous process streams [L19-33].

A number of studies have addressed the SFE of acidic components. One study investigated conditions to remove carboxylic and naphthenic acids from activated charcoal columns [L14-2]. Activated charcoal was used to remove acids suspected of causing fish toxicity from a petroleum refinery waste water effluent. Some unusual SFE conditions have been developed to analyze for acidic compounds. Resin acids and fatty acids were extracted from pulp mill sediments [L19-44]. SFE conditions used a methanol:formic acid (1:1, v/v) mixture in an initial static extraction which was followed by a dynamic extraction. The approximate 40% recovery of spiked resin acids was higher than recoveries obtained by Soxhlet extraction. Another unusual extraction employed benzoic acid/ethanol modified carbon dioxide to extract 2,4-dichlorophenoxy acetic acid from soil [L19-20]. Soil organic matter was found to limit the utility of this extraction.

Certain toxic metals can be extracted by SFE due to their nonpolar organometallic speciation. Methyl mercury was extracted from seafood after base digestion of the tissue and subsequent acidification to release CH3HgCl [L19-29]. Undefined organic arsenic species were extracted from dogfish muscle with CO_2 (5500 psi, 60°C, 29% methanol) [L19-37]. Subsequent HPLC analysis of the arsenic-containing extract verified retention of arsenic speciation. SFE has also been applied to extract tetraethyl-lead from gasoline tank sludge [L19-13].

Interestingly, SFE has been adapted for extraction of toxic heavy metals from a variety of matrices by reacting or complexing with specific additives to allow extraction to occur. For example, methanol-modified carbon dioxide that contained Li bis-(trifluoroethyl)dithiocarbamate (LiFDDC) ligand was used to extract bioaccumulated mercury from aquatic plants [L19 -14]. High extraction efficiencies for several metals (Cu, Pb, Sn, Cd) have been demonstrated by first complexing with organophosphorous reagents. One reagent, Kelex 100, allowed for the selective extraction of copper, whereas Cyanex 301, 302, and D2EHTPA were found useful for a range of metals in variety of matrices, including acidic samples [L19-7,9].

I.6 Pesticides from Soil

Out of the literature searches performed, the most extensive amount of work had been performed on SFE extraction of xenobiotic components from soil. Studies have addressed either a large-scale remediation goal [L8-33,39,68] or, more often, a trace analytical objective. Typically extractions are performed by subjecting the soil to a static supercritical fluid exposure followed by a dynamic extraction. Soil is often mixed with a drying agent such as magnesium sulfate before extraction [L8-26]. After extraction the supercritical fluid is then decompressed and the xenobiotic analytes quantitatively trapped in a solvent-filled receptacle, a sorbent bed, or on a glass fiber matrix embedded with modified silica particles [L8-29].

Numerous reports have discussed the use of different supercritical fluids [L8-37]. Fluids that have been investigated include carbon dioxide, nitrous oxide, and chlorodifluoromethane. The vast majority of studies employ carbon dioxide as the supercritical fluid. A wide variety of modifiers have been evaluated for enhancing extraction efficiency including methanol, toluene, pyridine, triethylamine (TEA), pyrrolidine, hexane, acetone, chloroform, methylene chloride, tributylphosphate, and ethyl acetate [L8-37,50,58]. Specialized applications requiring extractiion of basic compounds have found TEA-modified fluids useful; however, the vast majority of research has utilized methanol-modified carbon dioxide [L8-37]. Methanol-modified supercritical carbon dioxide has proven effective for extraction of organochlorine and organophosphorus pesticides from soil. Inclusion of modifiers (preferably methanol) is absolutely necessary to generate reasonably high recoveries of organochlorine or organophosphorus insecticides [L8-19,41,55,58,74].

Numerous investigators have touted the advantages of SFE over the more traditional solvent extraction (sonic agitation or Soxhlet extraction) approach [L8-3,5,10,11,18,22,24,31,38,40,43,46,51,61,63,73]. Principal advantages include producing less complex extracts (selective extraction) that have comparable or enhanced analyte recovery and precision as compared to solvent extraction. A consequence of the enhanced selectivity is that less sample clean-up (if any) is required prior to analysis. Additional advantages include replacement of harmful solvents with an environmentally benign extraction fluid, lower consumption of solvent, low expense, faster extractions, the ability to extract thermally labile analytes, and ease of interfacing with multidimensional chromatographic analysis instruments (described further below).

The distinction between analyte-spiked soils and soils that have been contaminated and aged under natural conditions is generally recognized [L8-9,14,16,52]. One study examined multivariate optimization of SFE parameters for freshly-spiked *versus* soil spikes that have aged in the soil [L8-8]. Solubility in the supercritical fluid was a critical determinant for efficient extraction of freshly-spiked soils, whereas extraction efficiency in aged soils was more diffusion rate limited (more dependent on the temperature of the extraction than pressure). Recovery from soils having a high organic carbon content is particularly difficult [L8-59,76]. One study found SFE distinctly superior over solvent extraction for recovering organochlorine pesticides from peat soil [L8-59]. As recalcitrant chemicals age in soil, they become more difficult to extract and require longer and/or stronger SFE conditions [L8-41]. Residues that are prone to metabolism may rapidly become incorporated or "bound" to the soil organic matter. SFE has been used to examine these bound residues. Generally, a more polar extraction medium (such as methanol) is superior to SFE for extracting these bound components [L8-28].

Certain studies describe unusual SFE applications. One application has been the determination of sorption coefficients (Kd) values [L8-12,21]. In this case, xenobiotics can be extracted from the equilibrated water/soil/analyte mixture directly without the separation of the aqueous solution from soil that is usually performed. Another application is the extraction of soils or sediment that contain high concentrations of elemental sulfur [L15,49]. One strategy is to reduce or remove sulfur interference by using a selective silver nitrate loaded silica in the extraction cell [L8-15]. Other studies address the difficult task of extracting very polar residues by the application SFE with*in situ* analyte derivatization, ion pairing, or ion displacement [L8-53,56].

A variety of commercially available instruments have been described and compared [L8-57,62]. One reference describes a portable SFE extractor based on novel hardware that, despite its reduced size and weight, maintains versatile capabilities [L8-6].

A number of studies have incorporated SFE as the first sample preparation step in a multidimensional chromatographic analysis scheme. For soil analysis, the on-line combination of SFE with supercritical fluid chromatography has been described most often [L8-35,54,66,67,70], although combinations with gas chromatography has also been described [L8-66,71].

I.7 Extraction of Pesticides from Plants and Animals

This literature search revealed a growing body of research that demonstrates SFE is a valid alternative to solvent extraction of extracting pesticides from biological tissues. This section can be artificially divided into analysis of plant or animal tissues, although the technical challenges presented by these complex biological matricies are clearly related.

Analysis of plants addresses a diverse range of tissues ranging from vegetable tissues [5-7,9,11,15,26] and oils [24], to seeds and cereal grains [8,14,19,22] and various fruits [15,26]. Samples with high alkaloid content have also been analyzed (tea and tobacco) [2,7]. Likewise the diversity of pesticides that have been addressed is impressive. Some investigators have adapted SFE techniques to examine radiolabeled pesticide residues that become bound during plant metabolism [9,12]. Most of the extraction conditions used for these studies are very similar. One important factor is the range of modifiers that can be applied for enhancing carbon dioxide extraction efficiency. Although only a peripheral objective of this study, one group examined the effect for different modifiers (methanol, ethanol, tetrahydrofuran, water, acetone, and acetonitrile) on analyte recovery for extracting pesticides from plant tissue [1]. Methanol-modified CO_2 gave the highest recoveries of the above modifiers in this study, a result consistent with the conditions used by most researchers. The majority of studies use dry tissue or, alternatively, mix the sample with anhydrous magnesium sulfate or diatomaceous earth (hydromatix) to sequester water before SFE extraction [13,16,17]. The extract can be collected after decompression in an organic solvent, a chilled receptacle, or a chromatographic sorbent bed that will quantitatively trap the analyte (in some cases this sorbent is chosen to facilitate further sample clean up) [24,27]. Overall, the results demonstrate comparable (and in some cases higher) recoveries for SFE compared to solvent extraction approaches. Often an extract generated by SFE contains lower quantities and number of interfering compounds [7,8]. In these “selective” extractions, the subsequent analysis required for target analyte quantification is significantly simplified. Other advantages of the SFE approach is the compatibility with on-line multidimensional separations, speed of extraction, and the reduction of hazardous extraction solvents [21,23,24].

SFE techniques used to exract pesticides from animal tissues have likewise found a diverse range of applications. A variety of muscle (chicken and bovine) as well as soft (rabbit liver and pig blood) tissues have been analyzed [3,4,18,25,26]. Analysis of butter fat and high fat content food products (ground hamburger) have been described [10,17,18,29]. SFE techniques have been applied to investigate organochlorine and PCB concentrations in human serum and bioaccumulation in adipose tissue [28]. Extraction conditions employed for animal tissue and subsequent extract clean-up and analysis are similar to the plant tissue techniques described above.

Table 1. Supercritical Fluid Extraction of Chemical Warefare Agents/Simulants

Compounds	Title	Reference	ID
Alkyl alkylphosphonofloridates; dialkyl alkylphosphonates	Comparison of supercritical fluid extraction with solvent sonication for chemical warfare agent determination in alkyd painted plates	*J. High Resolut. Chromatogr*., **21**:457-463 (1998)	L15(1)
Tabun; soman; sarin; methylphosphonic acid; dibenz[b,f](1,4)oxazepine	Analysis of chemical warefare agents in soil samples by off-line supercritical fluid extraction and capillary gas chromatography	*J. Microcolumn Sep*., **3**:505-512 (1991)	L15(2)
Chemical warfare agents	SFE, SFE/GC and SFE/SFC: Instrumentation and applications	J. Chromatogr. Libr., Vol. 53 - *Hyphenated Tech. Supercrit. Fluid Chromatogr. Extr*., pp. 275-304 (1992)	L15(3)
dimethylmethylphosphonate; 2-chloroethylethyl sulfide; diisopropylfluorophosphate; diisopropylmethylphosphate	Supercritical fluid extraction of chemical warfare agent simulants from soil	*J. Chromatogr*., **600**:273-277 (1992)	L15(4)

Table 2. Supercritical Extraction of Explosives

Chemical	Title	Reference	ID
TNT; RDX; HMX; PETN; NTO	Processing of energetic materials with supercritical CO_2	NATO ASI Ser., Ser.1, 14(Conversion concepts for commercial application and disposal technologie of energenic systems) pp. 247-258 (1997)	L7(3)
1,3,5-trinitrobenzene; 1,2-dinitrobenzene; 2,4-dinitrotoluene; 2,3-dinitrotoluene; 3,4 dinitrotoluene; 2,4,6-trinitrotoluene (TNT); 1,5-dinitronaphthalene; various PAH compounds	Supercritical CO_2 assisted liquid extraction of nitroaromatic and polycyclic aromatic compounds in soil	*J. Chromatogr. A*, **785**:227-238 (1997)	L7(4)
2-nitrotoluene; nitrobenzene; 3-nitrotoluene; 1,3,5-trinitrobenzene; 1,3-dinitrobenzene; 4-nitrotoluene; 2,4,6-trinitrotoluene; 2,4-dinitrotoluene; 2,6-dinitrotoluene; 2-nitroaniline; 3-nitroaniline; 2-amino-4-nitrotoluene; *p*-toluidine; 4-amino-2-nitrotoluene; diphenylamine; 2-amino-6-nitrotoluene; 2,6-diaminotoluene; 4-amino-4,6-dinitrotoluene	Application of supercritical fluid extraction (SFE) to organic contaminants in soils: Method development of explosives	*Vom Wasser*, **85**:215-228 (1995)	L7(11)
Explosives; chlorinated hydrocarbons; metals	Supercritical fluid (SCF) technologies: Assessment of applicability to installation restoration processes	Roy F. Weston Inc., Report AD-A281504, NTIS, pp. 1-111 (1994)	L7(14)
TNT; TNB; RDX; HMX	Evaluation of the use of supercritical fluids for the extraction of explosives and their degradation products from soil	Cold Regions Res. Eng. Lab., Report AD-A282338, NTIS, pp. 1-16 (1994)	L7(15)

Table 2. Supercritical Extraction of Explosives (continued)

TNT; RDX; HMX; 2-amino-4,6-dinitrotoluene	Supercritical fluid extraction of explosives and metabolites from composted soil	*Anal. Lett.*, **28**:1499-1511 (1995)	L7(16)
Nitroglycerin; PETN; 1,3,5-trinitrobenzene; TNT; 2,4-dinitrotoluene; RDX; 2-nitronaphthalene; 2,6-dinitrotoluene; 1-nitropyrene; composition B	Supercritical fluid extraction/gas chromatography with thermal desorption modulator interface and nitro-specific detection for the analysis of explosives	*J. Microcolumn Sep.*, **7**:23-28 (1995)	L7(17)
TNT	Extraction of explosives from soils with supercritical carbon dioxide	25th Int. Annu. Con., Energetic Materials - Analysis Characterization and Test Techniques, Fraunhofer-Institut fur Chemische Technologie (ICT), Pfinztal, D-76327/1, Germany, 74/1-74/16 (1994)	L7(20)
Nitroglycerine; PETN; TNT; 2,4-dinitrotoluene; RDX; ethylene glycol dinitrate; Doarit 1	Sample preparation by supercritical fluid extraction in explosives trace analysis	Advanced Analytical Detection of Explosives, Proc. 4th Int. Symp, J. Yinon (Editor), Kluwer, Dordrecht, Netherlands, pp. 55-65 (1992)	L7(22)
Nitroglycerin; trinitrotoluene; 2,4-dinitrotoluene; 2,3-dinitrotoluene	Coupled solid phase extraction-supercritical fluid extraction-online gas chromatography of explosives from water	*J. High Resolut. Chromatogr.*, **16**:473-478 (1993)	L7(23)
Gun propellants	Microanalysis of explosives and propellants by on-line supercritical fluid extraction	*J. Microcolumn Sep.*, **3**:127-140 (1991)	L7(24)
Ethylene glycol dintirate; PETN; RDX; tetradecane; hexadecane; heptadecane; octadecane	Charaterization of Semtex by supercritical fluid extraction and off-line GC-ECD and GC-MS	*J. High Resolut. Chromatogr.*, **15**:102-104 (1992)	L7(27)
Explosives; pesticides	Sample preparation by supercritical fluid extraction in environmental, food and	*Chromatographia*, **32**:527-537 (1991)	L7(28)

	polymer analysis		

Table 3. Supercritical Fluid Extraction of Hazardous Chemicals

Chemicals	Title	Reference	ID
o-dinitrobenzene	Extraction of hazardous chemicals from soil using supercritical fluids	*Hwahak Konghak*, **30**:379-386 (1992)	L19(1)
Hexachlorobutadiene; hexachlorobenzene; pentachlorobenzene; trichlorobenzene; tetrachlorobenzene; dichlorobenzene	Extraction of sediment-bound chlorinated organic compounds: Implications on fate and hazard assessment	*Water Sci. Technol.*, **33**:247-254 (1996)	L20(3)

Table 4. Supercritical Fluid Extraction of Poisons,Toxins, and Mycotoxins

Chemical	Title	Reference	ID
Deoxynivalenol; diacetoxyscirpenol; T-2 toxin	Supercritical fluid extraction and direct fluid injection mass spectrometry for the determination of trichothecene mycotoxins in wheat samples	*Anal. Chem.*, **58**:2421-2425 (1986	L19(9)
Zearalenone; fusarenone X; nivalenol; 3-acetyldeoxynivalenol; deoxynivalenol; 15-acetyldeoxynivalenol	Performance of modern sample preparation techniques in the analysis of Fusarium mycotoxins in cereals	*J. Chromatogr. A*, **815**:49-57 (1998)	L25(1)
Type A and B trichothecenes	Instrumental methods for determination of nonmacrocyclic trichothecenes in cereals, foodstuffs and cultures	*J. Chromatogr. A*, **815**:103-121 (1998)	L25(2)
Fusarenone X; nivalenol; 3-acetyldeoxynivalenol; deoxynivalenol; 15-acetyldeoxynivalenol	Determination of trichothecene mycotoxins in wheat by use of supercritical fluid extraction and high-performance liquid chromatography with diode array detection or gas chromatography with electron capture detection	*J. Chromatogr. A*, **795**:297-304 (1998)	L25(3)
Deoxynivalenol (DON)	The use of supercritical fluid extractionfor the determination of 4-deoxynivalenol in grains. The effect of the sample clean-up and analytical methods on quantitative results	*Chromatographia*, **46**:33-39 (1997)	L25(4)
Mycotoxins; carotenoids; lipids; flavor and fragrance compounds; steroid triterpenes; alkaloids	Analytical supercritical fluid extraction of natural products	*Phytochem. Anal.*, **7**:1-15 (1996)	L25(5)

Table 4. SupercriticalFluid Extraction of Poisons, Toxins, and Mycotoxins (continued)

Naturally occuring toxins	Applications of SFC/FTIR and SFC/MS to the analysis of food and natural product components	*Semin. Food Anal.*, **1**:133-144 (1996)	L19(1)
Deoxynivalenol (DON); diacetoxyscirpenol (DAS); T-2 toxin (T-2)	Supercritical fluid extraction of mycotoxins from feeds with analysis by LC/UV and LC/MS	*J. Liq. Chromatogr. Relat. Technol.*, **20**:537-551 (1997)	L19(2)
Nodularin; microcystin LR; microcystin YR; microcystin RR	Micellar electrokinetic capillary chromatography (MECC) of algal toxins	*J. High Resolut. Chromatogr.*, **20**:34-38 (1997)	L19(3)
Natural toxins and pollutants	Analytical supercritical fluid extraction for oils and lipid analysis	*Supercritical Fluid Technol. Oil Lipid Chem.*, J.W. King and G.R. List (Editors), AOCS Press Champaign, Illinios, pp. 387-428 (1996)	L19(4)
Benzene; phenol; *p*-choropheno; *m*-cresol	Supercritical carbon dioxide extraction of organic cotaminats from aqueous streams	*AIChE J.*, **37**:944-950 (1991)	L19(6)
Unspecified toxins	Supercritical fluid extraction of toxic organics from soils	*Dissertation Abstracts Int. B*, **51**:3807 (1991)	L15(1)
Mycotoxin T-2 from wheat and PCB extracted from urban dust	Supercritical fluid extraction/chromatography	*J. Flow Injection Anal.*, **3**:112 (1986)	L19(8)
Mycotoxins; carotenoids; lipids; flavor and fragrance compounds; steroid triterpenes; alkaloids	Analytical supercritical fluid extraction of natural products	*Phytochem. Anal.*, **7**:1-15 (1996)	L25(5)

Table 5. Supercritical FluidExtraction of Toxic (Leathal) Chemicals and Toxicants

Chemicals	Title	Reference	ID
Alkylphenol polyethoxylates (non-ionic surfactants) and alkylphenol metabolites [4-nonylphenol and 4-(tert)-octylphenol]	Distribution of alkylpenol compounds in Great Lakes sediments	*Environ. Toxicol. Chem.*, **17**:1230-1235 (1998)	L19 (4)
29 Different PCB's	Supercritical fluid extraction of polychlorinated biphenyls from soils and sediments	*Value adding solvent extraction*, ISEC'96, D.C. Shallcross, R. Paimin, L.M. Prvcic (Editors), U. of Melbourne, Dept. of Chemical Engineering, Parkville, Australia, pp. 1017-1022 (1996)	L19(6)
Extraction for Cu, Pb, Zn and Cd using chelator mobilization (Cyanex 302, 301 and D2EHTPA)	Development of a supercritical fluid extraction system for remediation of toxic metal contaminated environmental matrixes	Proc. Int. Top. Meet. Nucl. Hazard Waste Management, 6th Spectrum '96, Volume 2, American Nuclear Society, La Grange Park, Ill., pp. 967-973 (1996)	L19(7)
Toxic heavy metals (Pb, Cd, Cu, Zn) using CO_2 containing organophosphorus reagents (Cyanex 301 and 302 and D2EHTPA). Kelex 100 was selective for Cu+2	Extraction of toxic heavy metals using supercritical fluid carbon dioxide containing organophosphorus reagents	*Ind. Eng. Chem. Res*., **36**:1819-1826 (1997)	L19(9)
Phenobarbital	Analysis of drugs in human tissues by supercritical fluid extraction/immunoassay	*Proc. SPIE-Int. Soc. Opt. Eng*., **2941**(Forensic evidence analysis and crime scene investigation):19-23 (1997)	L19(10)
Variety of pesticides from plant	Pesticide residue analysis in plant	*J. Chromatogr. A*, **754**:397-410	L19(12)

tissue	material by chromatographic methods: Clean-up procedures and selective detectors	(1996)	
Tetraethyl-lead	Recovery of tetraethyl-lead from gasoline tanks sludges by SCF extraction	*Chem. Biochem. Eng. Q.*, **10**:63-67 (1996)	L19(13)
Mercury from plants using Li bis-(trifluoroethyl)dithiocarbamate (LiFDDC) ligand	Supercritical fluid extraction of bioaccumulated mercury from aquatic plants	*Environ. Sci. Technol.*, **30**:3111-3114 (1996)	L19(14)
Pesticides, herbicides, insecticides, and fungicides and their transformation products (substituted anilines, chlorophenols and ethyenethiourea) from water (review article)	Extraction methodology and chromatgraphy of the determiantion of residual pesticides in water	*J. Chromatogr. A*, **733**:217-233 (1996)	L19(16)
Pentachloropenol; polychlorinated dibenzo-*p*-dioxins; polychlorinated dibenzofuran	Extraction of toxic organic contaminants form wood and photodegradatioon of toxic organic contaminants	*Can. Pat. Appl.*, Chem. Abstracts 124:241094	L19(18)
Pesticides; ethanol; 2-propanol; phenol	High pressure extraction of organics from water	*Supercritical Fluid Process. Food Biomater*, S.S.H. Rizvi (Editor), Blackie, Glasgow, UK, pp.181-186 (1994)	L19(19)
2,4-Dichlorophenoxyacetic acid	Soil component interactions with 2,4-dichlorophenoxyacetic acid under supercritical fluid conditions	*Environ. Sci. Technol.*, **30**:1220-1226 (1996)	L19(20)
Toxic compounds from valve seals	Supercritical fluid extraction involving hydrofluoroalkanes for removal of toxic compounds form valve seals for medicine inhalers	*PCT Int. Patent Appl.*, Chem. Abstracts 123:266231	L19 (25)
2,3,6-trichlorobenzoic acid; 2,4-	Concentration and biotoxicity	*J. Environ. Sci. Health, Part A:*	L19(26)

dichlorobenzoic acid; carbon tetrachloride; hexachlorethane; 1,1,1-trichloroethane; 1,1-dichloroethane; 1,1-dichloroethylene; trichloroethylene; pentachlorophenol; 2,4,6-trichlorophenol; 2,4,5-trichlorophenol; hexachloroacetone; 2,4-dichlorophenol; tetrachloroethylene; *trans*-1,2-dichloroethylene; 1,1-dichloroacetone; 3-chlorobenzoic acid; 2-chloropropene; 1,1-dichloropropene; 2,5-dichlorophenol; 2-chloropropionic acid; hexachloropropene	assay of dilute aqueous solutions of volatile chlorinated organics using supercritical fluid extraction	*Environ. Sci. Eng. Toxic Hazard. Subst. Control*, **A30**:1867-1890 (1995)	
Methylmercury from seafood	Determination of methylmercury after supercritical fluid extraction	*J. AOAC Int.*, **78**:1124-1125 (1995)	L19(29)
p-chlorophenol; phenol	Separation of phenolic pollutants from dilute solutions using supercritical carbon dioxide and nitrous oxide	*Sep. Sci. Technol.*, **30**:683-695 (1995)	L19(23)
1,2-dichloroethane; 1,1,2-trichloroethane; 1,1,2,2-tetrachloroethane	Measurement and modeling of extraction of chlorinated hydrocarbons from water with supercritical carbon dioxide	*J. Supercrit. Fluids*, **7**:201-209 (1994)	L19(35)
Planar PCB's (non-ortho and mono-ortho-substituted) in biological samples (blood, serum, milk, and crab hepatopancreas)	Determination of planar PCB's by combining online SFE-HPLC and GC-ECD or GC/MS	*Anal. Chem.*, **66**:4068-4073	L19(36)

Organic arsenic species from dogfish muscle	Optimization of arsenic supercritical fluid extraction with detection by inductively coupled plasma mass spectrometry	*J. Anal. At. Spectrom.*, **9**:975-979 (1994)	L19(48)
Toxic phenolic components	Selective extraction of phenolic components from Ginkgo biloba extracts using supercritical carbon dioxide and off-line capillary gas chromatography/mass spectrometry	*Phytochem. Anal.*, **4**:178-182 (1993)	L19(39)
PAH; chlorinated insecticides (lindane, endrin, toxaphene, heptachor, methoxychlor); phthalates; chlorinated phenols; hexachlorobenzene; PCB's; atrizine; simazine; others	Determination of organic compounds in water by liquid solid extraction followed by supercritical fluid elution and capillary column gas chromatography/mass spectrometry	*National Meeting of the Am. Chem. Soc., Div. Environ. Chem.*, **33**:313-315 (1993)	L19(41)
Polychlorinated dibenzo-p-dioxins (PCDD's); dibenzofurans (PCDF's)	Supercritical fluid extraction and cleanup with capillary GC-ion trap mass spectrometry for detemination of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in environmental samples	*J. Chromatogr. Sci.*, **30**:357 (1992)	L19(42)
Pulp mill resin acids; fatty acids	Supercritical carbon dioxide extraction of resin and fatty acids from sediments at pulp mill sites	*J. Chromatogr.*, **594**:309-315 (1992)	L19(44)
PCB; DDT	Supercritical fluid extraction and catalytic oxidation of toxic organics from soils	U.S. Environ. Prot. Agency, Research Div., EPA/600/9-87/018F, *Proc. -- Int. Conf. New Front. Hazard. Waste Manage.*, 2nd, pp. 383-397 (1987)	L19(47)

Carboxylic acids; naphthenic acids	Use of supercritical fluid extraction and fast atom bombardment mass spectrometry to identify toxic chemicals from a refinery effluent adsorbed onto granular activated carbon	*Chemosphere*, **32**:1669-1679 (1996)	L14(2)
Chlorinated aromatics; chlorinated pesticides; polychlorinated biphenyls; chlorinated phenols	Role of entrainers in supercritical fluid extraction of chlorinated aromatics from soils	*Chemosphere*, **23**:1085-1095 (1991)	L14 (4)
Dichoromethane; ethylene dibromide; 4-nitrobiphenyl; 2-nitrofluorene; fluoroanthrene	Determination of volatile and semivolatile mutagens in air using solid adsorbents and supercritical fluid extraction	*Anal. Chem*., **63**:1644-1650 (1991)	L15(5)

Table 6. Superctritical Fluid Extraction of Pesticide from Soil

Quinclorac (3,7-dichloro-8-quinoline carboxylic acid)	Residue analysis of quinclorac in soil by supercritical fluid extraction and fluorogenic derivatization coupled with high performance liquid chromatography	*Han'guk Nonghwa Hakhoechi*, **40**:442-446 (1997)	L8(1)
Chlorinated hydrocarbons; polycyclic aromatic hydrocarbons; nitrogen- or phosphorous-containing pesticides	Distribution and mobility of organic micropollutants in River Elbe floodplains	*Chemosphere*, **37**:63-78 (1998)	L8(2)
Chlorothalonil	Comparison of supercritical fluid and Soxhlet extraction methods for the determination of chlorothalonil from cranberry bog soils	*J. Agric. Food Chem*., **46**:499-503 (1998)	L8(3)
Various polycyclic aromatic hydrocarbons; atrazine; hydroxyatrazine; deethylatrazine; triazine	Supercritical-fluid extraction coupled with immuonaffinity clean-up for the trace analysis of organic pollutants in different matrixes	*Chromatographia*, **46**:529-536 (1997)	L8(4)
Parathionethyl; triallate; pirimicarb; fenvalerate; fenpropimorph	Effects of modifiers, adsorbents, and eluents in supercritical fluid extraction of selected pesticides in soil	*J. Chromatogr. A*, **786**:155-161 (1997)	L8(5)
Lindane; phenanthrene; tributyl phosphate; pyrene; chrysene; aldrin; diazinon; atrazine; ethoprop	A man-portable supercritical fluid extractor	*Field Screening Methods Hazard. Wastes Toxic Chem*., Proc. Int. Symp., Volume 1. Air and Waste Management Association, Pittsburgh, PA, pp. 650-657 (1995)	L8(6)

4,4'-Dichlorobenzophenone; tetradifon; malathion; chlorobenzilate; chlorpyrifos; bromopropylate; procymidone; endosulfan (II); vinclozolin; tolclofos methyl	Quantitative analysis of pesticides in postconsumer recycled plastics using off-line supercricical fluid extraction/GC-ECD	*Anal. Chem.*, **69**:3304-3313 (1997)	L8(7)
Atrazine; diuron; bensulfuron methyl	Extraction of pesticide reidues in soils using multivariate optimization and supercritical fluid extraction (atrazine, diuron, bensulfuron methyl)	M.M. Zhou, Dissertation, U. of Delaware, Newark, DE (1996)	L8(8)
Diuron; atrazine; bensulfuron	Effects of environmental variables and supercritical fluid extraction parameters on the extractability of pesticide residues from soils using a multivariate optimization scheme	*Environ. Sci. Technol*., **31**:1934-1939 (1997)	L8(9)
β-endosulfan and endosulfan sulfate	Extraction of β-endosulfan and endosulfan sulfate in soils with supercritical CO_2	*Environ. Behav. Crop Prot. Chem*., Proc. Int. Symp. Use Nucl. Relat. Tech. Stud. Environ. Behav. Crop Prot. Chem., International Atomic Energy Agency, Vienna, Austria, pp. 495-501 (1997)	L8(10)
Various pesticides (review article)	Extraction of pesticide residues from biological and environmental samples	*Environ. Behav. Crop Prot. Chem*., Proc Int. Symp. Use Nucl. Relat. Tech. Stud. Environ. Behav. Crop Prot. Chem., International Atomic Energy Agency, Vienna, Austria, pp. 111-125 (1997)	L8(11)
Atrazine	Atrazine sorption-desorption in field-moist soils	*Int. J. Environ. Anal. Chem*., **65**:223-230 (1996	L8(12)

Chloro derivatives of 1,3,5-triazine; deisopropylatrazine; atrazine; deethylatrazine	Online supercritical fluid extraction and high performance liquid chromatography for determination of triazine compounds in soil	*J. High Resolut. Chromatogr.*, **19**:700-702 (1996)	L8(13)
2,4-D; diuron; atrazine; deltamethrin	Supercritical fluid extraction of bound pesticide from soil	*Environ. Fate Xenobiot.*, 10th Proc. Symp. Pestic. Chem, A.A.M. Del Re (Editor), Goliardica Pavese, Pavia, Italy, pp. 533-541 (1996)	L8(14)
4,4'-DDT; γ-BHC; dieldrin; endrin; 4,4'-DDD; 2,4'-DDE; heptachlor; endosulfan; aldrin; α-BHC; β-BHC; δ-BHC; heptachlor epoxide; endosulfan sulfate; endrin aldehyde	Matrix effect on supercritical fluid extraction of organochlorine pesticides from sulfur-containing soils	*J. Chromatogr. A*, **754**:285-294 (1996)	L8(15)
Variety of pesticides (review article)	Effect of soil pesticide interactions on the efficiency of supercritical fluid extraction	*J. Chromatogr. A*, **754**:221-233 (1996)	L8(16)
Lindane; parathion-methyl; linuron; dichlobenil; terbuthylazine	Predicting the leachability of pesticides from soils using near-infrared reflectance	*J. Agric. Food Chem.*, **44**:2260-2265 (1996)	L8(17)
Naphthalene; 5-methyl-3-heptanone; *n*-tetradecane	Supercritical fluid extraction -- a rapid extraction method for the characterization of contaminated soil	*Soil Environ.*, **5**(Contaminated Soil 95, Vol. 1):499-500 (1995	L8(18)
Lindane; dieldrin; heptachlor; malathion; simazine; propazine; aldrin; diuron; diazinon; isodrin; chlorfenvinphos; chlortoluron; isoproturon	Influence of pesticide-soil interactions on the recovery of pesticides using supercritical fluid extraction	*Analyst*, **121**:465-468 (1996)	L8(19)
Atrazine	Extraction of pesticide residues from soils using different methods	*Soil. Sci. Soc. Am. J.*, **60**:453-460 (1996)	L8(21)

	(lindane, DDT, dieldrin, Soxhlet extraction, sonication, high temperature distillation, supercritical fluid extraction)		
Carbaryl; aldicarb; carbofuran; atrazine; carbendazim; cyanazine; metolachlor	Supercritical fluid extraction-enzyme linked immunosorbent assay applications for determination of pesticide in soil and food	ACS Symposium Series, 621(*Immunoassays for residue analysis*), pp.439-449 (1996)	L8(22)
Carbaryl; propoxur; aminocarb; methiocarb	Supercritical fluid extraction of carbamate pesticides from soils and cereals	*Chromatographia*, **42**:206-212 (1996)	L8(23)
MCPA; anilazine; methidathion; dichlofluanid; metobromuron; desmedipham; phenmedipham; methabenzthiazuron; ethofumesate; isoproturon; iprodione; vinclozolin; triadimenol; metalaxyl; cymoxanil; penconazole; diflufenican; tebuconazole	Screening of pesticide-contaminated soil by supercritical fluid extraction (SFE) and high performance thin-layer chromatograpy with automated multiple development (HPTLC/AMD)	*Fresenius' J. Anal. Chem.*, **352**:464-469 (1996)	L8(24)
Hexachlorobanzene	Evaluation of a supercritical fluid extraction method for hexachlorobenzene from artificially spiked and naturally contaminated oil seeds and soil samples	*Int. J. Environ. Anal. Chem.*, **59**:1-13 (1995)	L8(25)
21 Organochlorine pesticides	Supercritical fluid extraction of organochlorine pesticides from soil	*Int. J. Environ. Anal. Chem.*, **59**:91-96 (1995)	L8(26)
DDT; lindane; diphenyl chloro derivatives; parathion methyl; pentachlorobenzene; atrazine;	Investigations on the supercritical fluid extraction of spiked organic pollutants from wet soils	*Fresenius' J. Anal. Chem.*, **353**:107-109 (1995)	L8(27)

carbetamide; methomyl; isoproturon			
Atrazine and its mtabolites	Characterization of mechanisms of pesticide retention in soils using the supercritical fluid extraction technique	*Int. J. Environ. Anal. Chem.*, **58**:379-385 (1995)	L8(28)
PCB's; pesticides; PAH	The use of ODS embedded glass fiber matrix disks as traps for supercritical fluid extraction	*Anal. Methods Instrum.*, **2**:48-51 (1995)	L8(29)
Various PAH; 2,4-D; malathion; fenitrothion; chlordane	The vehicle-portable analytical system of the emergencies science division of Environment Canada	*J. Hazard. Mater.*, **43**:141-154 (1995)	L8(30)
Atrazine; 2-hydroxyatrazine	Supercritical fluid extraction of triazine herbicides: A powerful selective analytical method	*Chromatographia*, **40**:705-711 (1995)	L8(31)
Dieldrin; 2,4-D; diuron; fonofos; atrazine; prometryn; pirimiphos-methyl; deltamethrin	Supercritical fluid extraction of bound pesticide residues from soil and food commodities	*J. Agric. Food Chem.*, **43**:1718-1723 (1995)	L8(32)
Methoxychlor; endrin; lindane	Solubility of chlorinated pesticides in supercritical carbon dioxide	*J. Chem. Eng. Data*, **40**:593-597 (1995)	L8(33)
Fenitrothion; aminocarb	Supercritical fluid extraction of pesticides from forestry matrixes	*J. Environ. Sci. Health*, **B30**:175-200 (1995)	L8(34)
Mixture of pesticides	Direct coupling of capillary supercritical fluid chromatography with supercritical fluid extraction using modified carbon dioxide	*J. High Resolut. Chromatogr.*, **17**:809-813 (1994	L8(35)
Diesel oil; benzene; toluene; xylene; ethylbenzene; PAH's; PCB's; chlorinated pesticides	Applications of supercritical fluid extraction in soil analysis	*LaborPraxis*, **18**:60-68 (1994)	L8(36)
Primicarb	Use of supercritical fluid extraction for pirimicarb	*J. Agric. Food Chem.*, **43**:395-400 (1995)	L8(37)

	determination in soil		
Pesticides; polychlorinated biphenyls; dioxins; polycyclic aromatic hydrocarbons (a review article)	Supercritical fluid extraction of analytes from environmental samples	*Analyst*, **119**:2381-2394 (1994)	L8(38)
2-Chlorophenol; 2,4,6-chlorophenol	Remediation of soil contaminated by 2-chlorophenol and 2,4,6-chlorophenol using supercritical fluid extraction	*Hazard. Ind. Wastes*, **26**:472-479 (1994)	L8(39)
Parathion; dichlorvos; endrin; ronnel; diazinon; tetrachloro-*m*-xylene; methidathion; decachlorobiphenyl; mirex; endrin daldehyde; tetrachlorvinphos	Supercritical fluid extraction of selected pesticides from fortified soils and determination by gas chromatography with electron capture detection	*J. Environ. Sci. Health*, **A29**:1801-1816 (1994)	L8(40)
Organochlorine pesticides	Optimization of supercritical fluid extraction of organochlorine pesticides from real soil samples	*J. Chromatogr. A*, **683**:167-174 (1994)	L8(41)
Triazine; hydroxytriazine	Structural elucidation and trace analysis with combined hyphenated chromatographic and mass spectrometric methods. Potential of using hybrid sector mass spectrometry-time-of-flite mass spectrometry for pesticide analysis	*J. Chromatogr. A*, **683**:141-140 (1994)	L8(42)
PAH's; N- and S-heterocyclics; chorinated phenols; pesticides	Direct comparison of Soxhlet and low- and high-temperature supercritical CO_2 extraction efficiencies of organics from environmental solids	*Anal. Chem.*, **66**:4005-4012 (1994)	L8(43)
Atrizine; pesticides; alkanes; fats; glyceridic oils; aromatic hydrocarbons	Comparative study of supercritical-fluid and Soxhlet extractions	*Spectra 2000*, **165**:57-63 (1992)	L8(44)

Pesticides	Extraction of pesticide residues in soil and blueberry plants by supercritical fluid extraction	R.G. Frazier, Dissertation, Rutgers, New Brunswick, NJ (1993)	L8(45)
Aldicarb; captan; carbofuran; atrazine; alachlor; metolachlor	Using supercritical fluid extraction and enzyme immunoassays to determine pesticides in soils	*Trends Anal. Chem.*, **13**:118-126 (1994)	L8(46)
Atrazine; hydroxyatrazine	Supercritical fluid extraction of triazine herbicides from solid matrixes	*Chromatographia*, **38**:514-519 (1994)	L8(47)
Chlorine and phosphorus-containing pesticides	Determination of selected organochorine and organophosphate pesticides in soils using supercritical fluid extraction, solid-phase extraction and gas chromatography with electron capture detection	J.L. Snyder, Dissertation, Villanova University, Villanova, PA (1993	L8(48)
Chlorinated pesticides, polychlorinated biphenyls, chorinated pesticides	Reduction/elimination of sulfur interference in organochlorine residue detemination by supercritical fluid extraction	*J. Chromatogr. A*, **662**:191-197 (1994)	L8(49)
Pesticides; petroleum hydrocarbons	Use of modifiers in on-line and off-line supercritical fluid extraction	*J. High Resolut. Chromatogr.*, **16**:368-371 (1993)	L8(50)
4,4'-DDT, γ-HCH, dieldrin, endrin, 4,4'-DDE, heptachlor, polychlorinated derivatives of biphenyl, HCB, aldrin, α-HCH, β-HCH, 2,4'-DDT, endosulfan I, hetachlor epoxide, mirex, 2,4'-DDE	Universal sample enrichment technique for organochlorine pesticides in environmental and biological samples using a redesigned simultaneous steam distillation-solvent extraction apparatus	*Anal. Chem.*, **65**:3677-3683 (1993	L8(51)
Deltamethrin	Fate of deltamethrin after nine	*J. Agric. Food Chem.*, **41**:1143-	L8(52)

	years of incubation in an organic soil under laboratory conditions	1151 (1993)	
(Pesticides, surfactants, phospholipids); 2,4-dichlorophenoxyacetic acid; benzene; naphthalene; toluene; alkanes; xylene; nitrobenzene; phenol; 2-chloroethylether; 2-ethylhexylphthalate; 1,2,4-trichlorobenzene; acenaphthylene; chrysene; 1,3-dichlorobenzene	Factors controlling quantitative supercritical fluid extraction (SFE) of environmental samples	*National Meeting Am. Chem. Soc., Div. Environ. Chem.*, **33**:291-294 (1993	L8(53)
PAH; polychorinated biphenyls (PCB's); organochlorinated pesticides	Applications of on-line SFE/SFC in environmental analysis	*J. Chin. Chem. Soc. (Taipei),* **40**:121-129 (1993)	L8(54)
Parathion; dichlorovos; endrin; ronnel; diazinon; methidathion; decachlorobiphenyl; mirex; endrin aldehyde; tetrachlorvinphos	The effect of instrumental parameters and soil matix on the recovery of organochlorine and organophosphate pesticides from soils using supercritical fluid extraction	*J. Chromatogr. Sci.*, **31**:1833-191 (1993)	L8(55)
2,4-D	Supercritical fluid extraction of 2,4-D from soils using derivatization and ionic modifiers	*Talanta*, **40**:147-155 (1993)	L8(56)
Chlorinated pesticides; diphenylethers; PAH	Evaluation of four supercritical fluid extraction systems for extracting organics from environmental samples	*LC-GC*, **10**:762-769 (1992)	L8(57)
Parathion; coumaphos; dimethoate; disulfoton; diazinon; carbofenthion	Extraction of organophosphorus pesticides from soil by off-line supercritical fluid extraction	*Analyst*, **118**:11-16 (1993)	L8(58)
p,p'-DDT; γ-HCH; dieldrin; TDE; *p,p'*-DDE; chloro derivatives of 1,1'-biphenyl; HCB; α-HCH; β-	Supercritical fluid extraction of polychlorinated biphenyls and pesticides from soil	*J. Chromatogr.*, **626**:135-143 (1992)	L8(59)

HCH; *o,p'*-DDT; PCB (28, 118, 153, 138, 52, and 101); β-Hepo			
Halogenated and sulfur-containing pesticides	Use of coupled SFE-GC-AED for the analysis of sulfide and halide pesticides	*Analusis*, **20**:S9-S11 (1992)	L8(60)
Parathion; endrin; ronnel; diazinon; methidathion; DCB; mirex; endrin aldehyde	Comparison of supercritical fluid extraction with classical sonication and Soxhlet extractions for selected pesticides	*Anal. Chem*., **64**:1940-1946 (1992)	L8(61)
PAH; pesticide; hop bitter acids	Supercritical fluid extraction in the analytical laboratry. A technique whose time has come	ACS Symp. Ser., 488(*Supercritical Fluid Technology*), pp. 266-287 (1992)	L8(62)
Fats; glyceridic oils; paraffin oils; PAH; alkanes	Supercritical fluid extraction versus Soxhlet sample prparation. A comparative study for extraction and analysis of organics in solid matixes	ACS Symp Ser., 488(*Supercritical Fluid Technology*), pp. 221-236 (1992)	L8(63)
Atrazine; bentazon; alachlor; permethrin	Extraction of pesticides from contaminated soil using supercritical carbon dioxide	U.S. Environ. Prot. Agency, Res. Div., EPA-600/9-91/047, *Proc. Int. Workshop Res. Pestic. Treatment/Disposal/Waste Management*, pp.100-110 (1992)	L8(64)
Nitroaromatic compounds (36), haloethers (19), organochlorine pesticides (42)	Supercritical fluid extraction in environmental analysis	ACS Symp Ser., 488(*Supercritical Fluid Technology*), pp. 179-205 (1992)	L8(65)
γ-BHC, hexachlorabenzene, aldrin, α-BHC, heptachlor epoxide, aroclor 1260, chlordane	A multiple sample extraction and on-line system for the analysis of chlorinated compounds	*Chemosphere*, **23**:1109-1116 (1991))	L8(66)
Pesticides; explosives	Sample preparation by supercritical fluid extraction in environmental, food and polymer	*Chromatographia*, **32**:527-537 (1991	L8(67)

	analysis		
Chlorinated aromatics; chlorinated pesticides; polychlorinated biphenyls; chlorinated phenols	Role of entrainers in supercritical fluid extraction of chlorinated aromatics from soils	*Chemosphere*, **23**:1085-1095 (1991)	L8(68)
Pesticide; herbicide; PCB's	Supercritical fluid extraction as sample preparation technique	*Chem. Mag.*, **17**:12-15 (1991)	L8(69)
Fenitrothion; esfenvalerate; diniconazole	Application of supercritical fluid extraction-supercritical fluid chromatography to pesticide residue analysis	*Anal. Sci.*, **7**:567-572 (1991	L8(70)
Lindane, *p,p'*-DDT, PCB's	The use of supercritical-fluid extraction in environmental analysis	*Fresenius' J. Anal. Chem.*, **339**:470-474 (1991)	L8(71)
Organochlorine pesticides (41); organophosphorus pesticides (47)	Supercritical fluid extraction and its application to environmental analysis	*J. Chromatogr. Sci.*, **28**:468-476 (1990)	L8(72)
Fenitrothion; esfenvalerate; diniconazole	Determination of residual pesticides in soils, crops, and animals, after extraction with supercritical fluids	Patent, Chem. Abstract 112:134507	L8(73)
Diuron; linuron	Supercritical fluid extraction and chromatography of representative agricultural products with capillary and microbore columns	*J. Chromatogra. Sci*, **27**:534-539 (1989)	L8(74)
Lindane; aldrin	Extraction of pesticides from soil with supercritical carbon dioxide	*J. High Resolut. Chromatogr. Chromatogr. Comm. (HRC&CC)*, **11**:726 (1988)	L8(75)
Soil-bound ^{14}C-labeled pesticide residues	Supercritical methanol: An efficacious technique for the extraction of bound pesticide residues from soil and plant	*J. Agric. Food Chem.*, **34**:70-73 (1986)	L8(76)

	samples		

Table 7. Supercritical Fluid Extraction of Pesticides from Plant and Animal Tissue

Chemical	Title	Reference	ID
Diuron; tribenuron methyl	Modifier effects in the supercritical fluid extraction of solutes from clay, soil, and plant materials	*Anal. Chem.*, **65**:1462-1469 (1993)	#1
Diniconazole; fenitrothion; esfenvalerate	Application of supercritical fluid extraction/supercritical fluid chromatography to pesticide residue analysis	*Anal. Sci.*, **7**:567-572 (1991)	#2
β-HCH; γ-HCH; heptachlor epoxide; chlordane; dieldrin; endrin; *p,p'*-DDD, *p,p'*-DDE; *p,p'*-DDT; heptachlor; aldrin	Application of supercritical fluid extraction of biological tissue samples for the determination of polychlorinated organics	*Chemosphere*, **19**:33-38 (1989)	#3
Hexachlorobenzene; β-HCH; γ-HCH; aldrin; heptachlor epoxide; chlordane	Supercritical fluid extraction and cleanup procedures for determination of xenobiotics in biological samples	*Chemosphere*, **20**:873-880 (1990)	#4
Norflurazon	Extraction of norflurazon residues in cotton seeds with supercritical CO_2	*Chromatographia*, **40**:432-434 (1995)	#5
Atrazine and its metabolites	Supercritical fluid extraction of triazine herbicides: A powerful selective analytical method	*Chromatographia*, **40**:705-711 (1995)	#6
Carbofuran; carbaryl	Off-line SFE-CZE analysis of carbamate residues in tobacco samples	*Chromatographia*, **42**:323-328 (1996)	#7
Chlorpyrifos methyl; malathion	Application of Supercritical Fluid	*Intern. J. Environ. Anal. Chem.*,	#8

	Extraction fo Analysis of Organophosphates in Cereals	**60**:139-144 (1995)	
Atrazine; hydroxyatrazine; deethylhydroxyatrazine; 2-chloro-4,6-diamino-*s*-triazine; dieldrin; carbofuran; 2-hydroxycabofuran	Supercritical methanol: An efficacious technique for the extraction of bound pesticide residues from soil and plant samples	*J. Agric. Food Chem.*, **34**:70-73 (1986)	#9
Heptachlor; heptachlor epoxide; dieldrin; endrin; lindane; *o,p'*-DDT	Supercritical fluid-based cleanup technique for the separation of organochlorine pesticides from fats	*J. Agric. Food Chem.*, **39**:1871-1874 (1991)	#10
Fluazifop-P-butyl; fluazifop-P	Supercritical fluid extraction of the fortified residues of fluazifop-P-butyl (fusilade II) and its major metabolite, fluazifop-P, in onions	*J. Agric. Food Chem.*, **41**:84-88 (1993)	#11
Deltamethrin; pirimiphos-methyl; fonofos; dieldrin; atrazine	Supercritical fluid extraction of bound pesticide residues from soil and food commodities	*J. Agric. Food Chem.*, **43**:1718-1723 (1995)	#12
Imidacloprid; methiocarb; methiocarb sulfoxide; chlorothalonil; chlorpyrifos; endosulfan I; endosulfan II; endosulfan sulfate; methamidophos	Supercritical fluid extraction of pesticides from vegetables using anhydrous magnesium sulfate for sample preparation	*J. Agric. Food Chem.*, **44**:1780-1784 (1996)	#13
Dimethoate; methyl parathion; pirimiphos-methyl; chlorpyrifos; malathion; dieldrin; methoxychlor; carbofuran	Optimization of experimental conditions for the supercritical carbon dioxide extraction of pesticide residues from grains	*J. AOAC Int.*, **76**:857-864 (1993)	#14
Various Pesticides (40 in all)	Development of a sample preparation technique for supercritical fluid extraction for multiresidue analysis of pesticides in produce	*J. AOAC Int.*, **78**:831-840 (1995)	#15

Methamidophos	Extraction of methamidophos residues from vegetables with supercritical fluid carbon dioxide	*J. AOAC Int.*, **78**:867-873 (1995)	#16
Various organochlorine and organophosphorus pesticides	Enhanced supercritical fluid carbon dioxide extraction of pesticides from foods using pelletized diatomaceous earth	*J. Assoc. Off. Anal. Chem.*, **74**:661-666 (1991)	#17
Bendicarb; methiocarb; carbaryl	Mixed adsorbent for cleanup during supercritical fluid extraction and three carbamates pestisides in tissues	*J. Chromatogr. A*, **657**:223-226 (1993)	#18
Sulfonylurea herbicides	Supercritical fluid extraction coupled with supercritical fluid chromatography for the separation of sulfonylurea herbicides and their methabolites from complex matrices	*J. Chromatgr.*, **435**:63-71 (1988)	#19
Aldrin; α-chlordane; γ-chlordane; *4,4'*-DDE; dieldrin; γ-HCH (lindane); hexachlorobenzene; oxychlordane; pentachorobenzene	Supercritical fluid extraction of sythetic organochorine compounds in submerged aquatic plants	*J. Chromatogr.*, **632**:119-125 (1993)	#20
Linuron; diuron	Supercritical fluid extraction and chromatography of representative agricultural products with capillary and microbore columns	*J. Chromatogr. Sci.*, **27**:534-539 (1989)	#21
Diazinon; pyrimiphos-methyl; fenitrothion; chlorpyriphos; ethion	Analysis of organophosphorous pesticides in rice by supercritical fluid extraction and quantitation using an atomic emission detector	*J. Chromatgr. Sci.*, **31**:445-449 (1993)	#22
Chlorpyrifos	Supercritical fluid extraction of chlorpyrifos methyl from wheat at parts per billion levels	*J. Microcolumn Sep.*, **1**:302-308 (1989)	#23

Diuron; bendiocarb; alachlor; carbaryl	Online supercritical fluid extraction/chromatography system for trace analysis of pesticides in soybean oil and rendered fats	*J. Microcolumn Sep.*, **3**:11-16 (1991)	#24
Abamectin (an insecticide)	The determination of abamectin from soil and animal tissue by supercritical fluid extraction and fluorescence detection	*Pestic. Sci*., **43**:141-146 (1995)	#25
Diazinon; chlorpyrifos; malathion; aldrin; diuron; lindane; endrin; DDT	Supercritical fluid extraction in the analytical laboratory	In: *Supercritical Fluid Technology Theoretical Applied Approaches in Analytical Chemistry*, F.V. Bright and M.E.P. McNally (Editors), ACS Symposium Series 488, American Chemical Society, Washington, D.C. (1992)	#26
7 Organochlorine pesticides and 14 polychlorinated biphenyl congeners	Relative abundance of organochlorine pesticides and polychlorinated biphenyls in adipose tissue and serum of women in Long Island New York	*Cancer Epidemiol., Biomarkers Prev.*, **7**:489-496 (1998)	L27(5)
15 Different pesticides	Studies on simultaneous determination of 15 pesticides in cereals by SFE and HPLC	*Shokuhin Eiseigaku Zasshi*, **39**:184-191 (1998)	L27(7)
Pesticide residues	Supercritical fluid extraction of pesticides from meat: A systematic approach for optimization	*Analyst*, **123**:1551-1556 (1998)	L27(8)