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7. ANALYTICAL METHODS

The purpose of this chapter is to describe the analytical methods that are available for detecting, measuring, and/or monitoring ethylbenzene, its metabolites, and other biomarkers of exposure and effect to ethylbenzene. The intent is not to provide an exhaustive list of analytical methods. Rather, the intention is to identify well-established methods that are used as the standard methods of analysis. Many of the analytical methods used for environmental samples are the methods approved by federal agencies and organizations such as EPA and the National Institute for Occupational Safety and Health (NIOSH). Other methods presented in this chapter are those that are approved by groups such as the Association of Official Analytical Chemists (AOAC) and the American Public Health Association (APHA). Additionally, analytical methods are included that modify previously used methods to obtain lower detection limits and/or to improve accuracy and precision.

7.1 BIOLOGICAL MATERIALS

Ethylbenzene can be determined in biological fluids, and tissues, and breath using a variety of analytical methods. Representative methods are summarized in Table 7-1. Most analytical methods for biological fluids and tissues use headspace gas chromatographic (GC) analysis. Breath samples are usually collected on adsorbent traps or in sampling bags or canisters, and then analyzed by GC.

The headspace method involves equilibrium of volatile analytes such as ethylbenzene between a liquid or solid sample phase and the gaseous phase. The gaseous phase is then analyzed by GC. There are two main types of headspace methodology: static (equilibrium) headspace and dynamic headspace, which is usually called the "purge-and-trap" method (Seto 1994). The static headspace technique is relatively simple, but may be less sensitive than the purge-and-trap method. The purge-and-trap method, while providing increased sensitivity, requires more complex instrumentation and may result in artifact formation (Seto 1994). Generally, an inert gas such as helium is passed over the biological sample at elevated temperature, and the purged volatile organic compound (VOC) is trapped onto an adsorbent polymeric resin (Tenax). The organic compound is thermally desorbed from the adsorbent followed by identification and quantitation using various detectors; flame ionization detection (FID) and mass spectrometry (MS) are used most often. Other sample preparation methods have been used, but less frequently. Solvent extraction permits concentration, thereby increasing sensitivity, but the extraction solvent can interfere with analysis. Direct aqueous injection is a very rapid method, but sensitivity is low and matrix effects can be a serious problem.

Table 7-1. Analytical Methods for Determining Ethylbenzene in Biological Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Whole blood	Whole blood samples were collected by venipuncture, sealed, and refrigerated. Extraction accomplished using a closed system purge and trap sampler	Capillary GC/MS	0.015–0.020 ppb	114–118	Ashley et al. 1992, 1994
Blood	Direct analysis via inertial spray extraction interface	GC/MS	<1 ppb	No data	St-Germain et al. 1995
Blood	Automated head space	Capillary GC/FID	0.002 µg/mL	90–110 (estimated)	Otson and Kumarathasan 1995
Blood	Extraction using dynamic headspace purge and trap system followed by thermal desorption to the GC	cap GC/FID	50 ng/L (calculated)	39	Fustinoni et al. 1996
Blood	Capillary blood samples extracted, sealed, mixed, and refrigerated. Gas phase sampled with gastight syringe and injected on column	GC/FID	2.7 µg/L	No data	Janasik et al. 2008
Urine	Purge and trap	Capillary GC/MS	No data	64–123 for model compounds	Michael et al. 1980
Urine	Extraction using dynamic headspace purge and trap system followed by thermal desorption to the GC	Capillary GC/FID	50 ng/L (calculated)	61	Fustinoni et al. 1996
Urine	Extracted to headspace	GC/FID	0.48 µg/L	No data	Janasik et al. 2008
Mother's milk	Purge and trap	Capillary GC/MS	No data	35–88 for model compounds	Michael et al. 1980
Brain tissue (post mortem)	Modified headspace (full evaporation technique)	Capillary GC-ITD	0.038 nmoles/sample	80–120	Schuberth 1996
Fat tissue	Add saline; freeze; thaw to 0 °C prior to analysis; add CS_2; inject into GC	GC/FID; confirmation GC/MS	No data	No data	Wolff et al. 1977
Adipose tissue	Purge and trap	Capillary GC/MS	No data	13–80 for halogen-ated hydro-carbons	Michael et al. 1980
Breath	Collection via spirometer into passivated canisters	Capillary GC/MS	low $\mu g/m^3$ levels	77–82	Thomas et al. 1991

Table 7-1. Analytical Methods for Determining Ethylbenzene in Biological Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Breath	Collection via spirometer onto charcoal traps; microwave desorption	Capillary GC/MS-SIM	0.2 µg/m^3 (1 L sampled)	No data	Riedel et al. 1996

FID = flame ionization detector; GC = gas chromatography; HPLC = high performance liquid chromatography; ITD = ion trap detector; MS = mass spectrometry; SIM = selected ion monitoring

A spirometer is usually used for the collection of breath samples. The device is used to provide clean air for inhalation and a mechanism for pumping exhaled breath into the collection media (Pellizzari et al. 1985). The breath samples are collected into Tedlar bags with subsequent adsorption onto Tenax traps (Pellizzari et al. 1985) or into passivated stainless steel canisters (Thomas et al. 1991). The Tenax traps are analyzed by thermal desorption GC techniques, and canister samples are analyzed by GC as well.

A sensitive and reliable method for identification and quantitation of ethylbenzene in samples of whole blood taken from humans following exposure to VOCs has been developed by Ashley and coworkers at the Centers for Disease Control and Prevention (Ashley et al. 1992, 1994). The method involves purge-and-trap of a 10-mL blood sample with analysis by capillary GC/MS. Anti-foam procedures were used, as well as special efforts to remove background levels of VOCs from reagents and equipment (Ashley et al. 1992). The method is sensitive enough (ppt levels) to determine background levels of VOCs in the population and provides adequate accuracy (114–118% recovery) and precision (16–44% relative standard deviation [RSD]) for monitoring ethylbenzene in the population. Using GC/FID to analyze capillary blood samples, Janasik et al. (2008) achieved a detection limit of 2.7 µg/L for ethylbenzene.

Few methods are available for the determination of ethylbenzene in body fluids and tissues other than blood. A modified dynamic headspace method for determination of ethylbenzene in urine, mother's milk, and adipose tissue has been reported (Michael et al. 1980). Volatiles swept from the sample are analyzed by capillary GC/FID. Acceptable recovery was reported for model compounds, but detection limits were not reported (Michael et al. 1980). Ethylbenzene in brain tissue may be determined using a headspace, capillary/ion trap detector (ITD) technique (Schuberth 1996). Recovery was good (80–120%) as was precision (≈20% RSD); the detection limit was reported as 4 ng/sample (0.038 nmoles) (Schuberth 1996). Janasik et al. (2008) achieved a detection limit of 0.48 µg/L for detection of ethylbenzene in urine using GC/FID. Biological monitoring for exposure to VOCs can also be based on identification of metabolites in urine, as analyzed by GC (Janasik et al. (2008). Sensitive, reliable methods are available for measuring ethylbenzene in breath. Exhaled breath is collected using a spirometer. The exhaled breath is collected into Tedlar bags for later transfer to adsorption tubes (Wallace et al. 1982), into passivated canisters (Thomas et al. 1991), or directly onto adsorbent traps (Riedel et al. 1996). The spirometer system, using adsorption onto Tenax traps and analysis by thermal desorption/capillary GC/MS techniques, was field-tested over the course of a very large exposure study (EPA 1987). The quantitation limit was ≈1 µg/m^3, recovery was 91–100%, and the precision for duplicate samples was ≤30% RSD (EPA 1987). Advances in the methodology include development of a more compact system with collection in 1.8-L canisters

(Thomas et al. 1992). Recovery of ethylbenzene is 92–104%, precision for duplicate samples is <3% RSD, and the detection limit was estimated as 3 μg/m^3 for ethylbenzene (Thomas et al. 1992).

7.2 ENVIRONMENTAL SAMPLES

Methods are available for determining ethylbenzene in a variety of environmental matrices. A summary of representative methods is shown in Table 7-2. Validated methods, approved by agencies and organizations such as EPA, ASTM, APHA, and NIOSH, are available for air, water, and solid waste matrices. Gas chromatography is the most widely used analytical technique for quantifying concentrations of ethylbenzene in environmental matrices. Various detection devices used for GC include FID, MS, and the photoionization detector (PID). Because of the complexity of the sample matrix and the low concentration of VOCs in most environmental media, sample preconcentration is generally required prior to GC analysis. Air samples may be collected and concentrated on adsorbent or in canisters for subsequent analysis. Methods suitable for determining trace amounts of ethylbenzene in aqueous and other environmental media include three basic approaches to the pretreatment of the sample: gas purge-and-trap technique, headspace gas analysis, and extraction with organic solvent.

Gas purge-and-trap is the most widely used method for the isolation and concentration of VOCs in environmental samples (Lesage 1993). The purge-and-trap technique offers advantages over other techniques in that it allows facile isolation and concentration of target compounds, thereby improving overall limits of detection and recovery of sample. Detection limits of <1 μg of ethylbenzene per liter of sample have been achieved (APHA 1995c; EPA 1984c, 1991b, 1992a). A serious drawback of this technique, particularly for quantitative analysis, is interference by impurities found in the stripping gas (EPA 1994c).

A purge-and-trap method with GC/FID analysis (Otson and Williams 1982) or GC/MS (Otson and Chan 1987) has been reported for the analysis and quantitation of ethylbenzene in environmental samples. Detection limits of <0.1 μg/L for GC/FID analysis and 0.1 μg/L were reported. Accuracy was also good, 74–88% (Otson and Chan 1987; Otson and Williams 1982).

Extraction with organic solvents (liquid-liquid extraction) provides a simple, rapid screening method for semi-quantitative determination of ethylbenzene in aqueous samples containing limited number of VOCs, but is less effective for aqueous samples containing large numbers of VOCs. Furthermore, interference

Table 7-2. Analytical Methods for Determining Ethylbenzene in Environmental Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Occupational air	Collection on charcoal adsorbent tube; desorption with CS_2	GC/FID	0.001–0.01 mg/sample[a]	Bias -7.6%	NIOSH 1994a (NIOSH Method 1501)
Occupational air	Organic vapor passive dosimeter badges; desorbed using CS_2	GC/MS	0.01 ppm	No data	Bratveit et al. 2007
Ambient air	Collection on Tenax adsorbent; thermal desorption	Capillary GC/MS	20 ng estimated[a]	No data	EPA 1988a (Method TO-1)
Ambient air	Collection in passivated stainless steel canisters	Capillary GC/MS or PID or FID	No data	No data	EPA 1988b (Method TO-14)
Ambient air	Collection on Tenax adsorbent; thermal desorption	Capillary GC/MS	2 ng[a]	No data	Pellizzari et al. 1993 (IARC Method 6)
Ambient air	Collection in canisters	GC/MS	0.2 ppbv	bias -8.1%	McClenny and Fortune 1995 (CLP Method)
Ambient air	Collection on multisorbent traps; automated preconcentration	Capillary GC/MS	0.036 ppbv	102	Oliver et al. 1996
Ambient air	Collection on multisorbent traps; thermal desorption with modified cryofocussing	Capillary GC/FID	0.25 ppbv	98	Oliver et al. 1996
Indoor air	Collection on Tenax acsorbent; thermal desorption	GC/MS	0.05–0.2 µg/m^3	No data	Kostianinen 1995
In-vehicle air	Collection on Tenax or multisorbent traps; thermal desorption	Capillary GC/MS-SIM	No data	No data	Lawryk and Weisel 1996
Flue gas	Collection on adsorbent traps using probe; thermal desorption	Capillary GC/FID	0.05 µg/m^3 (estimated)	No data	Jay and Steiglitz 1995
Product emissions	Collection on charcoal traps; desorption with CS_2	Capillary GC/FID	No data	No data	Wadden et al. 1995
Tobacco smoke	Collection on multisorbent traps; thermal desorption	fused-silica PLOT column GC/MS	No data	No data	Barrefors and Petersson 1993

Table 7-2. Analytical Methods for Determining Ethylbenzene in Environmental Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Snow	SPME using DVB-coated PDMS fiber with a film thickness of 65 µm	GC/MS	0.20 µg/L	No data	Kos and Ariya 2006
Drinking water	Purge and trap	GC/PID	0.01–0.04 µg/L	98–101	EPA 1991a (EPA Method 502.2)
Drinking water	Purge and trap	GC/PID; confirmation on second column or GC/MS	0.002 µg/L	93	EPA 1991b (EPA Method 503.1)
Drinking water	Purge and trap	GC/MS	1–2 µg/L	No data	EPA 1991c (EPA Method 524.1)
Drinking water	Purge and trap	Capillary GC/MS	0.06 µg/L	96–99	EPA 1992a (EPA Method 524.2)
Drinking water	Purge and trap	GC/FID or GC/MS	low µg/L	84–114	ASTM 1999b (ASTM Method D 3871)
Drinking water	Direct injection	GC/FID	~1 mg/L	No data	ASTM 1999a (ASTM Method D 2908)
Waste water	Purge and trap	GC/PID; confirmation on second column	0.2 µg/L	98	EPA 1984c (EPA Method 602)
Waste water	Purge and trap	GC/MS	7.2 µg/L	100–103	EPA 1999 (EPA Method 624)
Water	Closed-loop stripping	Capillary GC/MS	50 ng/L (instrumental)	No data	APHA 1995a (Method 6040B)
Waste water	Purge and trap	GC/MS	7.2 µg/L		APHA 1995b (Method 6210B)
Waste water	Purge and trap	GC/PID; confirmation on second column or GC/MS	0.2 µg/L	93	APHA 1995c (Method 6220B)
Waste water	Purge and trap	GC/PID	0.01–0.05 µg/L	93	APHA 1995d (Method 6220C)

Table 7-2. Analytical Methods for Determining Ethylbenzene in Environmental Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Solid waste	Direct injection or purge and trap	Capillary GC/PID	~1 µg/L (soil, sediment); ~0.1 mg/kg (wastes)	101	EPA 1994d (SW846 Method 8021A)
Solid waste	Purge and trap	Capillary GC/PID	~1 µg/L (soil, sediment); ~0.1 mg/kg (wastes)	101	EPA 1995a 9SW846 Method 8021B, proposed)
Solid waste	Purge and trap	Capillary GC/MS	~5 µg/kg (soil, sediment)	99	EPA 1994e (SW846 Method 8260A)
Solid waste	Various options including purge and trap, headspace, closed system vacuum distillation	Capillary GC/MS	purge and trap: ~5 µg/kg (soil and sediment); ~0.5 mg/kg (wastes)	90–112 (purge and trap)	EPA 1995b (SW846 Method 8260B, proposed)
Plant foliage	Solvent extraction; filtration	Capillary GC/SM-SIM	50 pg/µL extract	No data	Keymeulen et al. 1991
Fish	Solvent extraction; cleanup on florisil column; solvent microextraction	GC/FID	5 µg/g[b]	98–102	Karasek et al. 1987
Fish and sediment	Homogenization; freezing and vacuum extraction	Capillary GC/MS	25 ppb[b]	Sediments, 97 recovery; fish, 76% average for all analytes	Hiatt 1981, 1983
Eggs	Headspace	Capillary GC/PID; confirmation by GC/MS	0.002 µg/mL	94 (white); 49 (whole); 21 (yolk)	Stein and Narang 1990
Fruits and vegetables	Solvent extraction; filtration	Capillary GC/MS-SIM	No data	No data	Górna-Binkul et al. 1996
Olives and olive oil	Headspace	Capillary GC/MS	Low µg/kg levels	No data	Biedermann et al. 1995

Table 7-2. Analytical Methods for Determining Ethylbenzene in Environmental Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Cooked meat	Azeotropic distillation using Kilens-Nickerson estractor	Capillary GC/MS	6 µg/kg	No data	Gramshaw and Vandenburg 1995
Food containers (polystyrene)	Incubation with DMF; headspace	Capillary GC/FID; confirmation GC/MS	10 ppm	96–102	Sugita et al. 1995

[a]Sample detection limit will depend upon volume sampled. Value is estimated instrumental detection limit.
[b]Method detection limits were not provided; estimates cited are based on lowest concentrations used for method performance evaluation.

CS_2 = carbon disulfide; DMF = dimethylformamide; DVB = divinylbenzene; FID = flame ionization detector; GC = gas chromatography; MeOH = methanol; MS = mass spectrometry; PDMS = polydimethylsiloxane; PID = photoionization detector; PLOT = pourous-layer open tubular; SIM = selected ion monitoring; SPME = solid phase microextraction; UV = ultraviolet spectrophotometry

from the organic extraction solvent (hexane) makes it more difficult to completely identify all components (Karasek et al. 1987; Otson and Williams 1981).

Ethylbenzene may be determined in occupational air using collection on multisorbent cartridges, solvent desorption and analysis by GC/FID (NIOSH 1994a). Accuracy is very good (-7.6% bias); detection limits depend upon the amount of air sampled. Ambient air samples may also be collected on adsorbent traps (EPA 1988a; Pellizzari et al. 1993) or in stainless steel canisters (EPA 1988b; McClenny and Fortune 1995). Recovery for Tenax traps is very good, ranging from 91 to 100% (EPA 1987), and detection limits of 0.01 ppm have been reported (Bratveil et al. 2007). Little information on accuracy is available for multisorbent traps, but good recovery (102%) has been reported (Oliver et al. 1996). Bias of -8.1% for canister collection has been reported (McClenny and Fortune 1995). Detection limits depend upon the amount of air sampled, but values in the sub-ppb range have been reported (Kostiainen 1995; McClenny and Fortune 1995; Oliver et al. 1996). Organic vapor passive dosimeter badges may be used to determine personal exposure; the hydrocarbons are desorbed and analyzed by GC with GC/MS. Detection levels of 0.01 ppm for ethylbenzene have been reported (Bratveit et al. 2007). Purge-and-trap methodology is used most often for determination of ethylbenzene in water and hazardous wastes (Lesage 1993). The method was developed by Bellar and Lichtenberg (1974) for waste water. An inert gas is bubbled through the sample to strip out volatile components. The analytes in the gas stream are adsorbed onto sorbent traps, then thermally desorbed into the GC column. Very low detection limits for drinking water are reported for the purge-and-trap method with GC/PID (0.002–0.04 μg/L) (EPA 1991b). Accuracy is very good (93–101% recovery) (EPA 1991b). While the method is quite selective, confirmation using a second GC column or GC/MS is recommended (EPA 1991b). A sensitive (0.06 μg/L) and reliable method (96–99% recovery; <10% RSD) for drinking water uses capillary column GC/MS (EPA 1992a). Purge-and-trap methodology with analysis by GC/PID or GC/MS is used for waste waters (APHA 1995b, 1995c, 1995d; EPA 1984c, 1999). The detection limits are lower for GC/PID (0.2 μg/L) (EPA 1984c) than for GC/MS (7.2 μg/L) (EPA 1984b), but confirmation on a second column is recommended (EPA 1984c) when PID is used. Recovery and precision are very good (98–103% recovery; ≤10% RSD) (EPA 1984c, 1999).

Soil, sediment, and solid waste samples are difficult to analyze. Volatilization during sample handling and homogenization can result in ethylbenzene losses. The wet sample is usually dispersed in a solvent, then added to water for purge-and-trap/GC analysis (EPA 1994c; Minnich et al. 1997) or analyzed by high performance liquid chromatography (HPLC) (Dawson et al. 2008). Capillary GC/PID or GC/MS analysis provides detection limits in the low ppb range for soil and sediment and in the sub-ppm range for

solid wastes (EPA 1994d, 1994e, 1995a, 1995b). Minnich et al. (1997) reported detection limits as low as 1.7 ng/g using the GC method.

Few methods are available for the determination of ethylbenzene in fish and biota. A method for the determination of ethylbenzene in fish at low ppm levels using solvent extraction with GC/FID analysis has been reported (Karasek et al. 1987). A procedure to identify and quantify ethylbenzene in fish samples by vacuum distillation with capillary column GC/MS has been reported (Hiatt 1981, 1983). Recovery of 98–102% from spiked fish tissue was reported, but detection limits were not reported (Hiatt 1981). Purge-and-trap/capillary GC/MS has also been used for the determination of ethylbenzene in fish. Performance data for fish tissue samples were not reported (Dreisch and Munson 1983).

Few methods are available for the determination of ethylbenzene in food. Available methods involve solvent extraction (Górna-Binkul et al. 1996), headspace purge (Biedermann et al. 1995), and azeotropic distillation (Gramshaw and Vandenburg 1995) followed by capillary GC/MS or GC/PID analysis. Detection limits are in the low µg/kg range (Biedermann et al. 1995; Gramshaw and Vandenburg 1995). Little performance data are available. Recoveries from 21% (egg yolk) to 94% (egg white) were reported for headspace/capillary GC/PID analysis of eggs (Stein and Narang 1990).

Screening methods and field-portable methods may be useful analytical tools. Soil screening for petroleum hydrocarbons, including ethylbenzene, can be conducted using immunoassay procedures (EPA 1995e). Sensitivity is in the ppm range. Solid phase microextraction (SPME) has been tested as a screening method for water (Shirey 1995). The method is used in conjunction with capillary GC techniques. Portable GCs have been used for field monitoring of air (Berkley et al. 1991), water (Driscoll and Atwood 1993), soil (Driscoll and Atwood 1993), and hazardous waste (Overton et al. 1995). There are several studies that compare portable GC methods with laboratory methods (Berkley et al. 1991; Driscoll and Atwood 1993).

7.3 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of ethylbenzene is available. Where adequate information is not available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of

research designed to determine the health effects (and techniques for developing methods to determine such health effects) of ethylbenzene.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

7.3.1 Identification of Data Needs

Methods for Determining Biomarkers of Exposure and Effect.

Exposure. Exposure to ethylbenzene can be determined by the detection of mandelic acid and phenylglycolic acid in urine or by direct detection of ethylbenzene in human blood. Environmental exposures to ethylbenzene can result in detectable levels in human tissues. Existing methods for the determination of ethylbenzene in blood have the sensitivity necessary (0.008–0.012 ppb) (Ashley et al. 1992) to detect and measure low to trace levels of ethylbenzene in blood that might be present in the general population, as well as concentrations of ethylbenzene that might be associated with specific health effects. Methods for measurement of ethylbenzene in exhaled breath are sensitive enough (low $\mu g/m^3$) (Thomas et al. 1991) to provide background levels of ethylbenzene in the general population as well as to measure exposure. Additional performance information would be helpful, as would further development of a portable breath collection system. Information on levels of ethylbenzene in tissues is limited and the existing methods are not as well characterized. Improvements in the sensitivity of the methods for measuring concentrations of ethylbenzene in tissues and additional performance data would be helpful.

Methods for measuring metabolites and biomarkers for ethylbenzene are shown in Table 7-3. Methods exist for measuring ppm levels of ethylbenzene metabolites in urine (Ogata and Taguchi 1987, 1988; Sollenberg et al. 1985). They are sufficiently sensitive for measuring occupational exposure to ethylbenzene. These analytical methods are reliable and precise, but may not be sensitive enough to measure non-occupational exposure. Improvements in the sensitivity of the methods for measuring concentrations of ethylbenzene in tissues, and improvements in the sensitivity for measurement of metabolites in urine would allow better assessment of the correlation between levels in these media and observed health effects.

Table 7-3. Analytical Methods for Determining Biomarkers of Ethylbenzene in Biological Materials

Sample matrix	Sample preparation	Analytical method	Sample detection limit	Accuracy percent recovery	Reference
Urine (MA)	Dilution; centrifugation	HPLC/UV	MA 5 ng injected	MA 100–102	Ogata and Taguchi 1988
Urine (MA and PGA)	MeOH addition; centrifugation	HPLC	PGA $8.5x10^3$ µg/L MA $10x10^3$ µg/L	PGA 101 MA 102.6	Ogata and Taguchi 1987
Urine (MA and PGA)	Filtration; solvent extraction; evaporation and dissolution	HPLC/UV	MA, PGA $1.5x10^3$ µg/L	No data	Sollenberg et al. 1985
Urine (MA and PGA)	Filtration; solvent extraction; evaporation and dissolution	ITP	MA $6.1x10^3$ µg/L PGA $3.0x10^3$ µg/L	No data	Sollenberg et al. 1985

HPLC = high performance liquid chromatography; ITP = isotachophoresis; MA = mandelic acid; PGA = phenylglyoxylic acid; UV = ultraviolet (detection)

Effect. No specific biomarkers of effect for ethylbenzene were identified.

Methods for Determining Parent Compounds and Degradation Products in Environmental Media. Sensitive methods are available for measuring background levels of ethylbenzene in air, water, and wastes, the media of most concern for exposure of the general population and those populations located near hazardous waste sites. Few methods are available for measuring levels of ethylbenzene in fish, plants and biota. Detection limits in the low ppb range have been reported (Dreisch and Munson 1983; Hiatt 1981; Karasek et al. 1987; Keymeulen et al. 1991), but other performance data are generally lacking. Few methods are available for measuring levels of ethylbenzene in food. Little performance data are available for the available methods. Although several good analytical methods are available for detecting ethylbenzene in some environmental media, validated, reliable methods for measuring ethylbenzene in fish and foods are needed. These would be helpful in evaluating the potential for human exposure and health effects that might result from ethylbenzene contamination.

Methods for detecting environmental degradation products of ethylbenzene in environmental media are summarized in Table 7-4. Although methods are available for detecting major environmental degradation products (1-phenylethanol, acetophenone, benzaldehyde, for example) in reaction mixtures, it is not known whether these methods have the sensitivity and specificity for application to environmental media. Sensitive, reliable methods for determining degradation products in air, water, and waste would be helpful.

7.3.2 Ongoing Studies

The Environmental Health Laboratory Sciences Division of the National Center for Environmental Health, Centers for Disease Control and Prevention, is developing methods for the analysis of ethylbenzene and other volatile organic compounds in blood. These methods use purge and trap methodology, high-resolution gas chromatography, and magnetic sector mass spectrometry, which give detection limits in the low ppt range.

Table 7-4. Analytical Methods for Determining Environmental Degradation Products of Ethylbenzene

Sample matrix	Preparation method	Analytical method	Sample detection limit	Accuracy percent recovery	Reference
Reaction mixtures	Solvent extraction; concentration	Capillary GC/FID	No data	No data	Ehrhardt and Petrick 1984
Reaction mixtures	Centrifugation; solvent extraction; concentration	GC/FID; confirmation GC/MS	No data	No data	Fukuda et al. 1989

FID = flame ionization detector; GC = gas chromatography; MS = mass spectrometry