6. ANALYTICAL METHODS

The purpose of this chapter is to describe the analytical methods that are available for detecting and/or measuring and monitoring 1,3-butadiene in environmental media and in biological samples. The intent is not to provide an exhaustive list of analytical methods that could be used to detect and quantify 1,3-butadiene. Rather, the intention is to identify well-established methods that are used as the standard methods of analysis. Many of the analytical methods used to detect 1,3-butadiene in environmental samples are the methods approved by federal agencies 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 refine previously used methods to obtain lower detection limits, and/or to improve accuracy and precision.

6.1 BIOLOGICAL MATERIALS

No standardized method to test for the presence of 1,3-butadiene in biological materials presently exists. Only a limited number of techniques have been employed to determine this compound in biological materials.

An early method for the determination of 1,3-butadiene in blood was developed in 1944 (Miller 1978). It involves heating a blood sample containing iodine pentoxide to 200 °C, followed by determining the amount of 1,3-butadiene present by titrating any free iodine (produced during the reduction of iodine pentoxide) with sodium thiosulfate. This method is not specific to 1,3-butadiene; thus, its usefulness in obtaining an accurate indication of human exposure to 1,3-butadiene is unlikely.

Techniques for the determination of ^{14}C-labeled 1,3-butadiene in rat or mice blood and tissue after experimental exposure to enriched material have appeared in the literature (Bond et al. 1986, 1987). 1,3-Butadiene is removed from the sample matrix by vacuum distillation or by sparging with an inert gas. The desired material is recovered by collection in a cryogenic trap. The amount of 1,3-butadiene can then be ascertained by measuring the activity in the traps by scintillation counters. This technique cannot be applied to measure 1,3-butadiene exposure for the general population. However, the sample preparation step may be amenable to standardized gas chromatography (GC) techniques presently used in the determination of other organic compounds.

A technique for the determination of 1,3-butadiene in margarine samples was reported by Starting and Gilbert (1984). The margarine sample is placed in a vial, sealed, and heated to 70°C where it is allowed to equilibrate for 1 hour. The amount of 1,3-butadiene in the sample is determined by withdrawing a headspace sample, and injecting it directly into a GC equipped with a mass spectrometer (MS) detection system. Quantitation is obtained by

comparison of the peak height to that of a standard of known concentration. The sensitivity of this method allows quantitation down to 0.001 mg/kg (1 ppb). A similar headspace technique was used to test for the presence of butadiene in olive oil, vegetable oil, and yogurt samples (McNeal and Breder 1987).

6.2 ENVIRONMENTAL SAMPLES

Standardized methods for determining 1,3-butadiene in environmental samples are limited to air samples, as no methodology has been described for analyzing this compound in water or soil samples (EPA 1982, 1986, 1988a). A representative list of the methods available for the determination of 1,3-butadiene in air samples can be found in Table 6-l. The determination of 1,3-butadiene in personal air can be obtained using the procedure outlined in NIOSH Method 1024 (NIOSH 1987), which is described below.

The air sample is obtained by passing a known volume of air (3-25 L) through a set of tandem coconut charcoal tubes, which adsorb 1,3-butadiene and remove it from the air stream. The collected 1,3-butadiene is then removed from the adsorption tube by extraction with methylene chloride. Injection of the methylene chloride solution into a GC equipped with a flame ionization detector (FID) separates 1,3-butadiene from any interfering compounds that may be present. The choice of chromatography column for this determination is not crucial, as long as it cleanly separates 1,3-butadiene from other compounds.

The estimated quantitation limit of this method is 0.02 ppm, with an applicable range of l-480 μg per sample (approximately 0.02-8.7 ppm) for a 25 L sample. The precision of this method appears to change as a function of the concentration being measured, due to desorption efficiencies changing as a function of sample concentration. With increasing concentration, the preparation of a standard becomes *more* difficult.

In NIOSH Method 1024, quantitation of 1,3-butadiene is accomplished by comparing the area under the sample's response signal to that of a known amount of 1,3-butadiene. The preparation and injection of a gaseous. 1,3-butadiene standard is a difficult procedure; it must be performed carefully or erroneous results will occur. Sample storage appears to dramatically affect the results of the measurement. Samples stored at -4°C displayed an average recovery of between 93% and 98% over a 21-day period, while samples stored at room temperature ranged from 61% to 95%. Literature methods for the determination of 1,3-butadiene in personal air samples overcome some of these problems (Hendricks and Schultz 1986; Lunsford 1987; Lunsford and Gagnon 1987).

1,3-Butadiene, along with other volatile hydrocarbons, has been found in ambient air samples by a technique that uses cryogenic concentration before GC analysis. This technique is performed by collecting a large volume of air in

TABLE 6-1. Analytical Methods for Determining 1,3-Butadiene in Environmental Samples

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Personal air	Pass air through charcoal tube CH_2Cl_2 desorption	GC/FID	0.02 ppm	No data	NIOSH 1987
Air	Collect air in Tedlar bag, concentrate on Tenax cartridge, thermal desorption	GC/FID	No data	No data	Stump and Dropkin 1985
Air	Pass air through charcoal tube, solvent desorption	GC/MS	No data	No data	Texas Air Control Board 1990
Air (real time)	Draw air into 12 foot sampling loop, direct injection	GC/MS	No data	No data	Texas Air Control Board 1990

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

a specially designed bag or other sampling container and concentrating the volatile components by condensation at low temperatures. The sample is separated into its components by GC and quantified with an internal standard. Numerous variations of this method were found in the literature (Lonneman et al. 1979; Neligan 1962; Stephens and Burleson 1967, 1969; Stump and Dropkin 1985).

6.3 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 1,3-butadiene is available. Where adequate information is not available, ATSDR, in conjunction with the National Toxicology Program (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 1,3-butadiene.

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 or eliminate the uncertainties of human health assessment. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

6.3.1 Data Needs

Methods for Determining Biomarkers of Exposure and Effect. No standardized method for the determination of biomarkers of exposure and effect for 1,3-butadiene was located. A recent paper has demonstrated that 1,3-butadiene forms a hemoglobin adduct in mice and rats (Sun et al. 1989b). However, the 1,3-butadiene used in this study was tagged with a radioactive tracer, a technique which is only rarely utilized in the determination of environmental exposure in humans. In conjunction with the data needs discussed in Chapter 2, a method to monitor the formation of a 1,3-butadiene adduct with human hemoglobin needs to be established. The development of an analytical technique to measure this biomarker of exposure can then be achieved. Once a unique biomarker has been identified and an experimental technique to detect it has been established, a quantitative assessment of routes and levels of human exposure to 1,3-butadiene can be undertaken.

No known biomarkers of effect specifically for 1,3-butadiene have been reported, but recent advances have been made (Gallagher 1989; Weston et al. 1989) in ^{32}P-post labelling and other DNA adduct assays.

Methods for Determining Parent Compounds and Degradation Products in Environmental Media. Data on the determination of 1,3-butadiene in environmental media were limited. 1,3-Butadiene in air samples has been detected by techniques routinely used for detecting volatile hydrocarbons (Stump and Dropkin 1985; Texas Air Control Board 1990). Procedures accepted for the determination of volatile hydrocarbons in other environmental media (soil, water, sediment, plants, etc.) may also be suitable for 1,3-butadiene. This question can be answered only by the data obtained from properly designed experiments. The information will assist in determining the prevalence of this compound in the environment and aid in a quantitative determination of human exposure to 1,3-butadiene.

6.3.2 On-going Studies

On-going studies performed by J. Pau at EPA's Atmospheric Research and Exposure Assessment Laboratory in Research Triangle Park, NC, on new analytical methods for the determination of 1,3-butadiene have been identified (EPA 1989b), although no other specific information was provided.