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Occupational Exposure of Workers to 1,3-Butadiene

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Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an extent-of-exposure study of the 1,3-butadiene monomer, polymer, and end-user industries to determine the size of the exposed workforce, evaluate control technologies and personal protective equipment programs, and assess occupational exposure to 1,3-butadiene. A new analytical method was developed for 1,3-butadiene that increased the sensitivity and selectivity of the previous NIOSH method. The new method is sensitive to 0.2 μg per 1,3-butadiene sample. Walk-through surveys were conducted in 11 monomer, 17 polymer, and 2 end-user plants. In-depth industrial hygiene surveys were conducted at 4 monomer, 5 polymer, and 2 end-user plants. Airborne exposure concentrations of 1,3-butadiene were determined using personal sampling for each job category. A total of 692 full shift and short-term personnel and 259 area air samples were examined for the presence of 1,3-butadiene. Sample results indicated that all worker exposures were well below the current OSHA PEL of 1000 ppm. Exposures ranged from less than 0.006 ppm to 374 ppm. The average exposure for all samples was less than 2 ppm. The present American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value for 1,3-butadiene is 10 ppm. To reduce the potential for occupational exposure, it is recommended that quality control sampling be conducted using a closed loop system. Also all process pumps should be retrofitted with dual mechanical seals, magnetic gauges should be used in loading and unloading rail cars, and engineering controls should be designed for safely voiding quality control cylinders.

Introduction

In the United States, 100% (2500 million pounds) of all the 1,3-butadiene is produced as a coproduct of ethylene manufacture. Styrene-butadiene rubber (SBR) and latex and polybutadiene rubber (BR) productions account for the two largest uses of 1,3-butadiene in the U.S. and approximately 1600 million pounds are used primarily in the tire industry. Polychloroprene (neoprene) rubber production ranks third with 200 million pounds (*1*).

The National Institute for Occupational Safety and Health (NIOSH) has estimated from their National Occupational Hazard Survey that 65,000 workers are potentially exposed to 1,3-butadiene (*2*).

Limited published data exist on the extent of worker exposure to 1,3-butadiene. These data are highly suspect because they are based on an analytical method that does not adequately separate 1,3-butadiene from other C_4 hydrocarbons. Also, there is likelihood of poor desorption efficiency at low levels and of the sample collection exceeding their volumetric capacity. It is believed that the historical monitoring results tend to overestimate exposure to 1,3-butadiene. Because of these data deficiencies, the use of the existing exposure data base in any risk assessment must be done with caution because of the imprecision and error in the estimates of past exposure.

Recent inhalation exposure studies of rats (*3*) and mice (*4*) to 1,3-butadiene found the induction of a carcinogenic response at multiple sites at levels of exposures below the Federal Guidelines of 1000 ppm.

Based on the positive results of the animal studies and the deficiencies in the available exposure data, NIOSH, through an Interagency Agreement with the U.S. Environmental Protection Agency's Office of Toxic Substances, conducted an extent-of-exposure study of the 1,3-butadiene industry. Between 1984 and 1987, NIOSH surveyed a total of 39 1,3-butadiene monomer, polymer, and end-user plants. The data generated from this study was to be used by the Occupational Safety and Health Administration (OSHA) in developing a new health standard for 1,3-butadiene. This effort also included the

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development of a new analytical method, the determination of occupational exposure to 1,3-butadiene, and the documentation of effective control technology and personal protective equipment programs. This paper addresses the current extent-of-exposure data obtained and provides recommendations for reducing potential exposure to 1,3-butadiene.

Applicable Standards and Recommended Limits

The current permissible exposure limit (PEL) of the U.S. Occupational Safety and Health Administration (OSHA) for 1,3-butadiene is 1000 ppm (2200 mg/m^3) (*5*). At the time of this report, OSHA had initiated a new rule-making process to reduce worker exposure to 1,3-butadiene. Based on reported animal carcinogenicity data, the American Conference of Governmental Industrial Hygienists (ACGIH) has included 1,3-butadiene as an "A2" industrial substance suspected of carcinogenic potential in man (*6*). A threshold limit value (TLV) of 10 ppm (22 mg/m^3) has been assigned to 1,3-butadiene. NIOSH recommends that 1,3-butadiene be regarded as a potential occupational carcinogen and teratogen and as a possible reproductive hazard (*2*).

Study Design

The study was divided into two phases and involved a detailed evaluation of the three industries using 1,3-butadiene: monomer, polymer, and end-users. The first phase of the study was to conduct walk-through surveys at 11 monomer production plants, 17 polymer plants, and 2 end-user plants. The walk-through surveys were used to define production, work practices, number of workers potentially exposed, personnel records, and engineering controls.

At the time of this study, 11 companies in the U.S. were producing 1,3-butadiene monomer at 16 plant locations. Walk-through industrial hygiene surveys were conducted at all 11 U.S. monomer producers. To conduct a study of the polymer industry it was first necessary to identify the different kinds of 1,3-butadiene polymers or products produced. Twenty-four polymers or products containing 1,3-butadiene were identified and 17 production facilities representing the 24 polymers were randomly selected for walk-through surveys.

Two plants from the end-user industry were randomly selected from a potential plant population that numbered in the hundreds. Because sytrene-butadiene rubber and polybutadiene rubber account for the two largest uses of 1,3-butadiene, a rubber tire plant and an industrial hose plant were selected. Walk-throughs and in-depth surveys were combined for this industry. The justification of combining the two surveys is based on the limited potential for 1,3-butadiene to present a potential exposure hazard in the end-user industry.

The second phase of the study was to conduct in-depth industrial hygiene surveys. This phase was similar to the first one, with the exceptions that both occupational air samples for 1,3-butadiene were collected and the engineering controls were evaluated during the in-depth surveys. In-depth surveys were conducted at four monomer plants, five polymer, and the two end-user plants. These facilities were chosen based on their representation of the monomer, polymer, and end-user group as a whole.

Effectiveness of Engineering Controls

Consumption and use of 1,3-butadiene occurs in enclosed processing systems at open-air plants. The different processing operations and the explosive nature of the gas necessitates the use of wide variety of process and control equipment. These operations incorporate a number of controls designed to prevent the release of chemical intermediates and products into the environment. Many of these controls are a major part of the process equipment, whereas others have been added for a specific purpose. Some controls are designed to reduce worker exposures that can arise from inhalation or skin contact, whereas other controls are intended to abate environmental releases. Frequently, the environmental controls can function indirectly to reduce the level of toxic contaminants in the workplace air.

The safe operation of the chemical plants that manufacture or consume 1,3-butadiene requires periodic maintenance on pumps, valves, reboilers, and heat exchangers, as well as scheduled maintenance on larger equipment such as fractionating towers. Prior to performing maintenance activities, equipment must be decontaminated for safe handling. The decontamination and repair operations present process workers and maintenance workers with a potential for exposure to 1,3-butadiene. Engineering controls are implemented in three operational categories: process flow, quality control (QC) samples, and transportation.

Process Flow

Leak prevention from pumps at 1,3-butadiene monomer and polymer facilities is accomplished through the use of various types of seals that isolate the interior of the pump from the atmosphere.

Seals can be grouped into two generic classes: packed and mechanical. Mechanical seals offer better protection against leaks than packed seals. These seals are further categorized as either single or dual mechanical seals. In a single mechanical seal application, the rotating seal ring and stationery element faces of the motor shaft are lapped to a very high degree of flatness to maintain contact throughout their entire mutual surface area. If these factors wear out or become misaligned, however, a single mechanical seal will release the material being transferred directly into the work environment. The release of 1,3-butadiene from leaky pump seals presents an exposure potential in the general work environment of the process and also to the various workers repairing the leaky pump.

However, with the dual mechanical seals, a liquid, usually oil, is circulated through the cavity between the two mechanical seals. The circulating liquid is normally maintained at a higher pressure than the process fluid. Any leakage of the 1,3-butadiene across the seal face causes the seal liquid to be released first, indicating a seal failure. This action provides additional protection over a single mechanical seal.

Quality Control Samples

A quality control (QC) program typically requires workers to perform three major tasks: *a)* collecting 1,3-butadiene samples using sampling cylinders, *b)* performing laboratory analysis of the samples, and *c)* purging/cleaning the sampling cylinders. Each task has individual controls associated with it.

In general, there are two types of sampling methods: the use of on-line gas chromatographs and manual sampling employing either an open-loop or closed-loop system. The use of on-line gas chromatographs may also decrease the need for some manual sampling.

Manual sample collection consists of attaching the sample cylinder (bomb) to fittings on the process equipment, opening the process stream in order to allow the sample to flow through the cylinder, closing off the sampling stream, and disconnecting the cylinder.

Open-loop atmospheric sampling systems represent the older technology and present greater potential for exposure. In these systems, the cylinder is attached to a process release valve, opened at both ends. A sample is taken following the release of 1,3-butadiene through the cylinder directly into the workplace. This stream of 1,3-butadiene detracts from the air quality in the work environment and may result in worker exposure through both inhalation and direct dermal contact. The mechanical nature of this sampling process lends itself to exposure because of the mechanical connection of the cylinder to the sample stream by means of a threaded fitting. The process technician can be exposed by leaks in the cylinder resulting from worn or cross threaded fittings.

The potential for worker exposure during sampling is greatly minimized by the use of closed-loop sampling techniques. These systems represent a recent solution towards minimizing the release of process fluid to the work environment during cylinder sampling. The closed-loop system allows the sampled fluid to circulate from the process through the cylinder, and back to the process. Sampling occurs by grabbing a sample of the process stream through the cylinder. Sampling lines connecting the process to the cylinder are a permanent part of the process equipment. Properly designed closed-loop systems also have provisions allowing the inspector to purge or evacuate the sample lines of 1,3-butadiene before removing the cylinder. Improperly purged sampling lines are a source of 1,3-butadiene exposure when the cylinder is disconnected because the sampling line is under positive pressure with respect to the work environment. The effectiveness of the closed-loop system is contingent on the proper fitting of the cylinder to the closed-loop system. Worn fittings will result in 1,3-butadiene leaks during sampling and voiding procedures.

Laboratory analyses of the quality control samples may present a potential for additional exposures through dermal contact or inhalation. The sample bombs are taken to the plant laboratory for analysis by instrumental methods (gas chromatography) and wet chemical procedures. The release of the 1,3-butadiene sample for analysis can consist of either direct connection of the sample bomb to analytical equipment (e.g., gas chromatograph) or the release of a small volume of the sample from the bomb into an open container. The connection of the bomb to analytical equipment can result in small releases of 1,3-butadiene into the laboratory workplace. Engineering controls in the laboratory may include dilution ventilation of the laboratory air, using laboratory hoods with adequate face velocities, and employing sample connections that minimize leakage and dead volume.

The complete voiding or purging of sample cylinders is performed following analysis in order to evacuate the bomb and make it available for reuse. Bomb voiding may be accomplished by several methods: *a)* manual or uncontrolled voiding of the bombs directly into the atmosphere, *b)* controlled voiding under laboratory hoods or enclosed vacuum vents, and *c)* controlled voiding of bombs by recycling to the process.

Using the first method, laboratory technicians hold the cylinder at arm's length while releasing 1,3-butadiene to the outside air; this appears to be a significant source of exposure to 1,3-butadiene. However, at most plants voiding is usually performed under laboratory hoods or vacuum tents.

Transportation

Transportation of 1,3-butadiene product to and from the monomer and polymer production facilities is accomplished using four transfer methods: pipelines, rail tank cars, tank trucks, and marine vessels. Of these methods, only pipeline transfer (which is a totally enclosed system) represents a situation, if properly maintained, where no exposure to or release of 1,3-butadiene occurs.

Monitoring the loading/unloading of the rail tank cars, tank trucks, and marine vessels may present a potential for 1,3-butadiene exposure. For rail tank cars the two types of fill gauges that are used to monitor the loading/unloading process are slip-tube and magnetic. The first type of gauge, the slip-tube gauge, achieves this task by releasing a small plume of 1,3-butadiene vapor to the ambient air. The vapor acts as a visual signal to the loading area process technician that the 1,3-butadiene in the tank car has reached a predetermined level. The second type of gauge, the magnetic gauge, which is a completely sealed metering system operating without the release of vapor into the air, can be considered an improvement over the slip-tube design. A magnetic ring or doughnut located inside the tank car floats on the surface of the 1,3-butadiene. As the tank car fills, the ring rises over an enclosed shaft. Inside the shaft is a metered steel rod that projects out over the top of the car. The extent of this projection is monitored by the loading area process technician and provides an accurate measure of the level of 1,3-butadiene in the tank car.

Monitoring the loading/unloading operation for tank trucks differs from that of rail tank cars in that the gauging system on the trucks is an open-ended rotameter that releases 1,3-butadiene into the atmosphere, thereby creating the potential for 1,3-butadiene exposure.

Marine vessels typically use slip-tube gauges similar to those used by rail tank cars for monitoring the loading/unloading process.

Sampling and Analytical Method

The major limitation at the start of the study was the sensitivity and selectivity of the analytical method for 1,3-butadiene (NIOSH method S-91) (*7*). The new method (NIOSH method 1024) is sensitive to 0.2 μg per sample (*8*) or 0.005 ppm for 25 L samples.

During the in-depth surveys, both personal and area sampling were performed. The samples were collected with SKC Model 224 and Gillian Model HFS-113A-UT portable low-flow air-sampling pumps. Samples were collected on tandem coconut-shell charcoal tubes. The forward tube contained 400 mg of coconut charcoal and acted as the primary collection medium. The backup tube contained 200 mg of coconut charcoal and acted to quantify the level of breakthrough. The charcoal tubes were connected to the pumps with plastic Tygon tubing. Samples were collected with low-flow pumps at a flow rate of 0.05 to 0.5 Lpm. Sample air volumes were limited to a minimum of 1 L and a maximum of 25 L. The samples were desorbed in methylene chloride and analyzed by high-resolution gas chromatography.

To assure the quality of results, sample blanks and quality control spikes were generated, analyzed, and reported in accordance with NIOSH Quality Assurance and Quality Control procedures (*9*). Field samples were refrigerated during shipment and storage. Samples were found to remain stable for at least 21 days when kept at −4°C.

In-Depth Site Selection Strategy

Site selection for the in-depth industrial hygiene surveys were designed to obtain a representative subset of the 1,3-butadiene industry to use in characterizing exposures by job title. To achieve this, the monomer production plants were divided into distinct subpopulations (strata) representing observed differences in the workplace environment (i.e., the presence or absence or controls, the mode of transportation, or the existence of other production procedures). A single plant within each stratum was selected, based on a scoring system that quantified the relative representation of each site. Four plants emerged as best representing the diversity of the work environments seen in the 1,3-butadiene monomer industry.

The site selection criteria for the five in-depth industrial hygiene surveys of the polymer industry were based on the information acquired during the 17 walk-through surveys. The final site selection for the in-depth surveys was based on the following criteria:

1. Five plants should be selected.
2. The plants selected should represent those polymers of greatest 1,3-butadiene consumption. The polymers were ranked according to their yearly comsumption. The five plants selected for in-depth surveys represented 85% of the consumption of 1,3-butadiene by product type, not volume.
3. The plants selected should have a large number of potential exposed employees, thus increasing the accuracy of subsequent risk assessments.
4. Each polymerization process should be represented (emulsion and solution).

The end-user industry was divided into the rubber tire industry and rubber products industry. Since little or no exposure to 1,3-butadiene was anticipated in the end-user industry, only one plant was selected from each industry group.

Industrial Hygiene Sampling Strategy

The 11 in-depth surveys were planned and scheduled to obtain personal and area air samples during normal production conditions. Exposure concentrations of 1,3-butadiene were determined for each potentially exposed job category using personal sampling. At least one worker in each exposed job category was monitored for a full shift. During each in-depth survey, three shifts were monitored over the course of 3 work days. Auxiliary jobs were also monitored in the production area where exposure to 1,3-butadiene was intermittent. Non-production jobs involving maintenance and laboratory workers were also evaluated to determine their potential for exposure. Area samples were conducted to determine the levels of workplace air in the general process area. Short-term personal samples (15–120 min) were also obtained of jobs/tasks to evaluate peak exposure during the performance of the task. The short-term samples were taken during quality control sampling, cylinder voiding, or whenever a job required a worker to open up a 1,3-butadiene line (i.e., maintenance).

Results and Discussion

Monomer Industry

A total of 117 personal samples (composed of 88 full shift and 29 short-term samples) were collected during the four in-depth surveys of the monomer industry.

Eight job descriptions were monitored during the in-depth surveys. Six of these jobs were tasks that required the worker to spend a majority of the time in the process area where the production, handling, or storage of 1,3-butadiene took place. Two of the titles described jobs that were performed in the quality control laboratories at each plant. In addition to the personal sampling of employees with specific job responsibilities, seven work areas and the general ambient air at the perimeter of the process were monitored for concentrations of 1,3-butadiene.

The personal samples were presented in Figure 1 by job title. The number of samples, arithmetic mean, median, range, and geometric mean and standard deviation are presented for each job title. Figure 2 presents the same descriptive statistics for the samples collected at each work area. The short-term results for both personal and area sampling are presented in Figure 3.

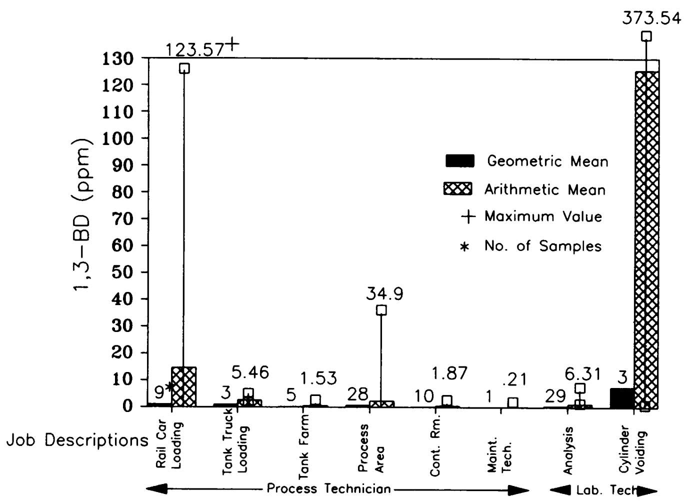

FIGURE 1. Four monomer plants, full-shift personal samples. The arithmetic mean was not used in the overall calculation for the total mean exposure. The 373 ppm was due to poor work practices at one plant and is not typical of the cylinder voiding activities observed in the industry.

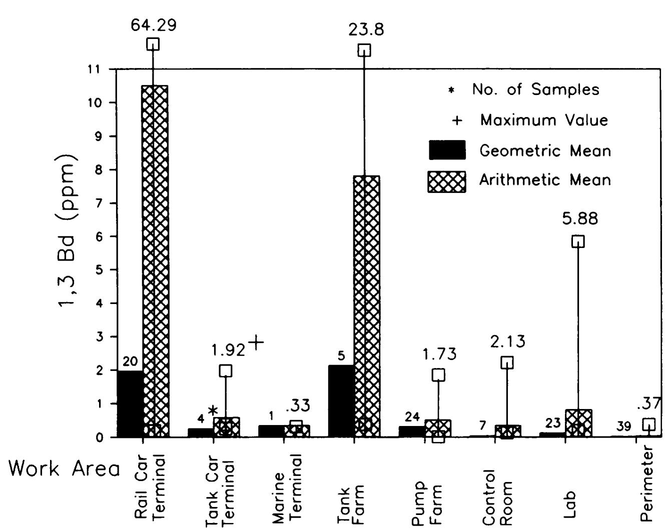

FIGURE 2. Four monomer plants, full-shift area samples.

A review of the personal exposures by job title (Fig. 1) suggested that those jobs requiring workers to handle or transport containers of 1,3-butadiene presented the greatest potential for exposure. Laboratory technicians voiding sample cylinders and process technicians loading or unloading tank trucks or rail cars had geometric mean exposures of 7.46, 1.02, and 1.00 ppm, respectively. All other job titles experienced geometric mean exposures of less than 1 ppm. Maximum exposures for two job titles exceeded 100 ppm, with one exposure for a laboratory technician reaching an 8-hr TWA of approximately 375 ppm. These two exposures were associated with poor work practices or uncontrolled emissions. In both cases there was a poor connection of threaded fittings, thus permitting the escape of 1,3-butadiene into the work environment. For the purpose of analysis, the two data points that exceeded 100 ppm were not used in the calculation of the arithmetic mean for the overall study. The results were not indicative of the work practices used throughout the industry.

Area concentrations of 1,3-butadiene were also detected at levels well below the OSHA PEL of 1000 ppm. A review of the 123 area monomer results in Figure 2 indicated that rail car terminals and tank storage farms had geometric mean concentrations of 1.96 and 2.12 ppm, respectively. Other work areas had geometric mean concentrations of less than 1 ppm. No full-shift area samples exceeded 100 ppm.

Figure 3 illustrates that the exposure potential will exceed 10 ppm for short-term sampling in all three types of periodic inplant activities—cylinder sampling, cylinder voiding, and maintenance. Short-term monitoring is intended to evaluate peak exposures during a job activity with a definite exposure potential. The highest short-term 1,3-butadiene concentrations are associated with the open-loop sampling (146 ppm) and cylinder voiding (108 ppm).

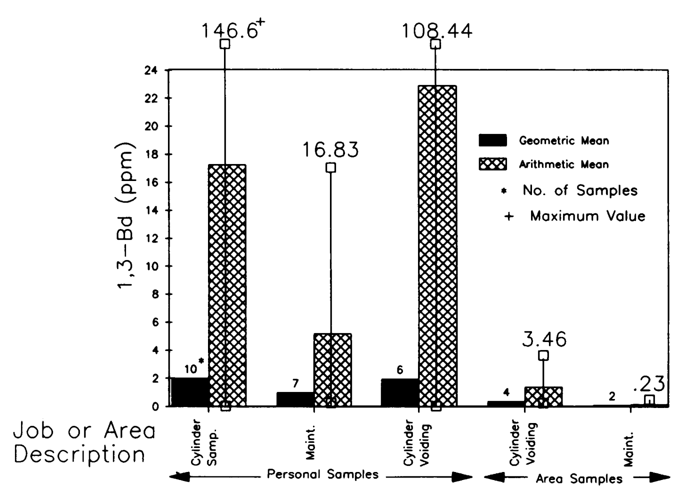

FIGURE 3. Four monomer plants, short-term personal and area samples.

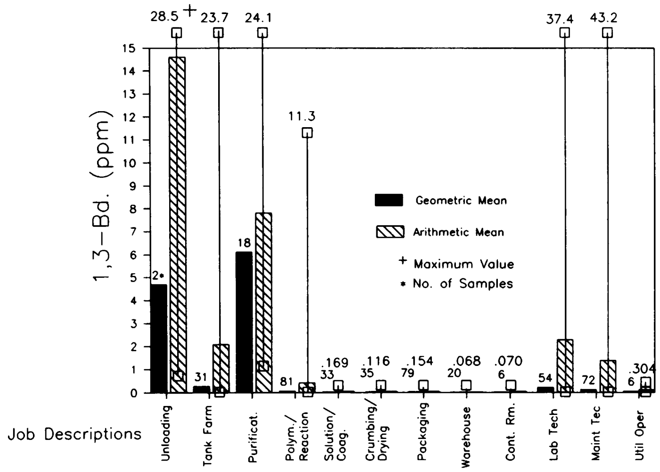

FIGURE 4. Five polymer plants, full-shift personal samples.

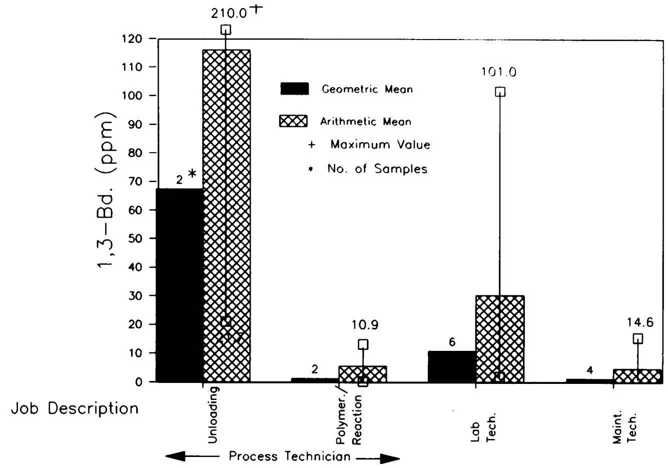

FIGURE 5. Five polymer plants, short-term personal samples.

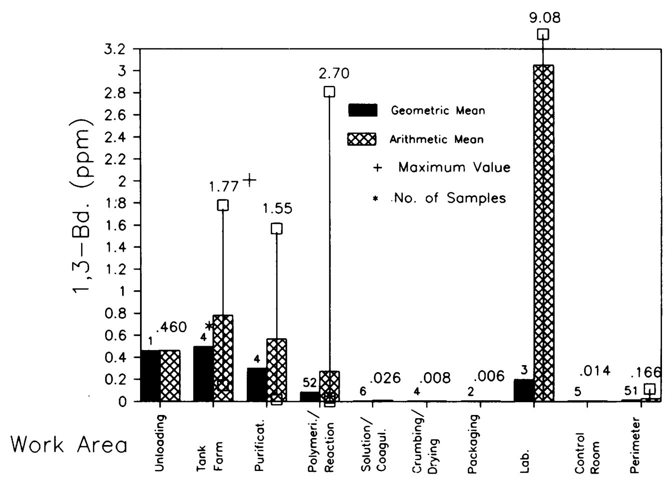

FIGURE 6. Five polymer plants, full-shift area samples.

Polymer Industry

A total of 451 personal samples and 132 area air samples (composed of 437 full-shift and 14 short-term samples) were collected during the five 1,3-butadiene polymer facility in-depth surveys.

Figures 4 and 5 provide a breakdown by job category/ work activity of the full-shift and short-term personal monitoring results, respectively, and present averages, ranges, and standard deviations for the measured 1,3-butadiene concentrations. Full-shift exposures for the different job categories range from a low of < 0.005 to a high of 43.2 ppm (Fig. 4), whereas the short-term exposures range from 0.088 to a high of 210 ppm (Fig. 5). The highest full-shift personal exposure was 43.2 ppm for a maintenance technician working on a 1,3-butadiene compressor. The highest short-term exposure was 210 ppm for a process technician (unloading area) sampling a barge for 1,3-butadiene. The short-term personal monitoring was conducted with the intention of identifying peak exposures during operation or activities that were considered to have a potential for exposure to 1,3-butadiene. The sampling results in Figure 5 show at least one short-term exposure to 1,3-butadiene greater than 10 ppm for all four types of periodic inplant job categories.

Figure 4 clearly shows that the six job categories that experience full-shift (personal) 1,3-butadiene exposures greater than 10 ppm (at least one sample) are the process technician in unloading, tank farm, purification, polymerization or reaction, laboratory technician, and maintenance technicians. These job categories had geometric mean exposures of 4.69, 0.270, 6.10, 0.062, 0.213, and 0.122 ppm, respectively. Geometric mean exposures for all other job categories were below 0.03 ppm. Maximum full shift exposures for laboratory and maintenance technicians exceeded 35 ppm (at least one sample).

A total of 132 area samples were obtained during the five polymer in-depth industrial hygiene surveys. Figure 6 provides a breakdown by work environment of the full-shift area monitoring results and presents averages, ranges, and standard deviations for the 1,3-butadiene concentrations. Full-shift 1,3-butadiene concentrations in the work areas ranged from 0.006 to 9.08 ppm. The maximum full-shift area concentration of 9.08 ppm was observed in the 1,3-butadiene GC/QC laboratory near the gas chromatograph. The threaded connections of the cylinder to the gas chromotagraph was the source of exposure. The cylinder was not in a ventilated exhaust hood. A total of 51 samples were taken at plant perimeter locations and a geometric mean of 0.013 ppm was calculated.

End-User Industry

A rubber tire plant and an industrial hose plant were selected to represent the end-user industry. The plants consumed styrene-butadiene rubber, polybutadiene, and acrylonitrile-butadiene rubber. A total of 124 personal samples were collected over three shifts during the survey (34 hose, 90 tire). The analytical results in Tables

Table 1. Summary of personal industrial hygiene samples at a rubber hose plant.

Job description	Number of samples	Results
Banbury operator	6	ND[a]
Mill operator	10	ND
Extruder (tuber) operator	11	ND
Extruder mill operator	6	ND
Curing press operator	1	ND
Total	34	

[a]ND = Nondetectable (limit of detection = 0.3 μg/sample).

Table 2. Summary of personal industrial hygiene samples of a rubber tire plant.

Job description	Number of samples	Results
Banbury operator	6	ND[a]
Cooling conveyer operator	6	ND
Calendering operator	13	ND
Extruder operator	11	ND
Wire winder	3	ND
Tube machine operator	9	ND
Tire builder	15	ND
Curing operator	21	ND
Tire repair and buffer	6	ND
Total	90	

[a]ND = Nondetectable (limit of detection is 0.3 μg/sample).

1 and 2 indicate that 1,3-butadiene was less than the limit of detection in all samples.

Conclusions

The 1,3-butadiene monomer and polymer processes are highly automated, and operators hence do not routinely spend much time in the process area. There are, therefore, few opportunities for occupational exposure greater than 10 ppm of 1,3-butadiene throughout most of the process. However, there are three categories of ancillary operations associated with the process that present a potential for exposure to 1,3-butadiene. These operations include: decontamination and maintenance of process equipment; sampling and analyzing of quality control samples; and loading and unloading the crude feed and 1,3-butadiene product. Seven distinct job categories have been identified as encountering potential for occupational exposure to 1,3-butadiene in these operations. Those job categories exposed were in the loading (0.08–123.6 ppm), and unloading area (0.77–28.5 ppm), tank farm (< 0.006–23.7 ppm), purification unit (1.33–24.1 ppm), polymerization or reaction area (< 0.006–11.3 ppm), laboratory (< 0.006–373 ppm), and maintenance technicians (0.006–43.2 ppm).

In summary, the monitoring results from the present NIOSH study for the 1,3-butadiene industry show that full-shift personal exposures for all job categories are well below the current OSHA PEL of 1000 ppm. A total of 692 personal full-shift and short-term and 259 area air samples were taken for 1,3-butadiene. Arithmetic mean full-shift personal exposures for all job categories was 2.7 ppm, which is below the ACGIH TLV of 10 ppm. A total of 951 air samples were collected during the study and 3.3% (31/951) were greater than 10 ppm. The results of the end-user industry document, on a very limited basis, that workers in this industry do not currently have measurable exposure to 1,3-butadiene.

The engineering controls and work practices that have been developed are effective in minimizing personnel exposures if these practices are properly used and maintained. Exposure, as evidenced from the short-term exposure data, will occur if the fittings on a closed-loop system are worn or improperly connected. In summary the monitoring data for the 1,3-butadiene industry show that personal full-shift exposures for all job categories can be maintained below 10 ppm by the application of effective engineering controls. Additional studies will have to be conducted to determine the feasibility of achieving lower concentrations of 1,3-butadiene (e.g., 1 ppm) for all job categories in the industry.

Short-term personal exposures may, however, exceed 10 ppm for operations such as bomb sampling, bomb voiding or maintenance; use of personal protective equipment (respirators) would be required to control peak exposures for these operations.

The new NIOSH analytical method 1024 is the preferred method. The enhanced sensitivity provided by the high-resolution chromatography should enable detection down to 0.005 ppm in a 25 L sample.

Recommendations

In the context of the current OSHA PEL for 1,3-butadiene (1000 ppm) and the ACGIH TLV of 10 ppm, the NIOSH study results indicate that the control programs in the 1,3-butadiene industry generally appear to maintain personal exposures below the present applicable limits. However, because of certain job-related exposures and the concern that 1,3-butadiene may present both a carcinogenic and teratogenic risk, the following additional control measures are recommended for production plants that may not already be implementing such controls.

1. For obtaining quality control cylinder samples, plants should consider converting to a closed-loop sampling system to lower the mean exposure to lab technicians and process technicians working in process areas.
2. Leaking pumps present an exposure potential to process technicians in the process areas. The release of 1,3-butadiene from such equipment can be controlled through the use of dual mechanical seals. Plants should consider retrofitting pumps having single mechanical seals with the more effective dual mechanical seals.
3. Because magnetic gauges are known to limit the release of 1,3-butadiene (and hence exposure to process technicians in the loading area) while load-

ing rail cars, plants should consider a program to convert to 100% magnetic gauges for monitoring rail-car filling operations.

4. As evident from the monitoring results for laboratory technicians conducting cylinder voiding, workers assigned to this task may be exposed to relatively high levels of 1,3-butadiene. Consideration should be given to using a laboratory hood or a vacuum exhaust with an enclosure for cylinder voiding. Furthermore, workers should be trained in the proper conduct of tasks such as cylinder voiding and cylinder sampling.
5. Maintenance technicians should use respirators with organic vapor cartridges when performing maintenance-related activities on process equipment.
6. The new NIOSH sampling and analytical method for 1,3-butadiene is recommended in areas of potentially low exposures and where there is a potential for interference with other C_4 compounds.

As evident from the results of the NIOSH monitoring study, the use of analytical methods specific to 1,3-butadiene is preferred for assessing 1,3-butadiene exposures.

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