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Benzene Exposure in the United States 1978–1983: An Overview

H.E. Runion, MA, MPH, and L.M. Scott, PhD

Due to the interest in reducing the benzene exposure limit from 10 to 1 ppm, the benzene exposure data collected since 1977 were compiled and evaluated. Some 38,000 data points representing either time-weighted air samples or persons exposed were collected from five industries which produce and/or use benzene and two government organizations. Of the reported data, 87% represented exposure levels of 1.0 ppm or less. Petroleum and chemical operations where elevated exposure levels were reported included petrochemical and bulk loading operations. Benzol and by-product plants in the iron and steel industry showed similar elevated results.

Key words: benzene exposure profile, U.S. benzene exposure, U.S. industry, exposure profile

INTRODUCTION

A renewed interest concerning the regulation of workplace benzene exposure standards was stimulated by the Public Citizen Health Research Group and a number of labor unions on April 14, 1983. The Occupational Safety and Health Administration (OSHA) was petitioned to issue an emergency temporary standard which, among other things, called for 1-part-per-million (ppm) time-weighted-average (TWA) criterion.

During the month of July 1983, OSHA rejected the petition but agreed to expedite the rule-making process and would at that time consider the merits of lowered exposure criteria. A completion date for release in the Federal Register as a proposed rule was targeted for June 1984.

In view of the above, a need was seen to compile worker exposure experience to benzene in United States industries since 1977. Such information should be of some significance when assessing the true risk to health.

The exposure data during the past 6 years should also provide some insight with respect to future trends involving workplace benzene levels. These results are particularly important in that they are a product of industry action and employee cooperation to protect their health when operating within the present 10-ppm OSHA standard.

Division of Medical and Health Resources, Industrial Hygiene Department, Gulf Oil Corporation, Pittsburgh.
Address reprint requests to Mr. H.E. Runion, Gulf Oil Corporation, P.O. Box 3240, Pittsburgh, PA 15230.
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APPROACH

All of the major trade associations whose member companies were considered as having some involvement with petrochemical operations and benzene or benzene-containing products or process intermediates were asked to provide 1978–1983 exposure data. Data were received from the American Petroleum Institute (API) (more than 30 companies provided data), Chemical Manufacturers Association (CMA) (nine companies provided data), American Iron and Steel Institute (AISI) (ten companies provided data), National Paint and Coating Association (NPCA) (three companies provided data), and Rubber Manufacturers Association (RMA) (eight companies provided data). Similarly, data were also received from OSHA (used data only when two or more samples collected) and National Institute of Occupational Safety and Health (NIOSH). The API data is current to about October 17, 1983, and may differ slightly from that which will ultimately be reported to OSHA. Unfortunately more detail involving the nature of the operations reflected by these data was not available from the trade associations.

It is believed that the data are all personnel sampling of 4 or more hours duration and are time-weighted averages. In all cases, information provided consisted of either number of sample results or employees exposed by ppm ranges. No data were provided relative to statistical parameters.

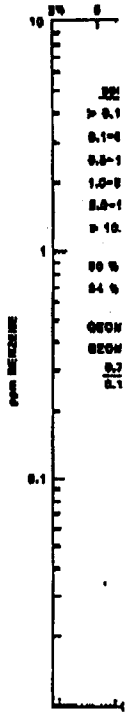
Most industrial hygienists and others involved with the analysis of workplace exposure data subscribe to the thesis that such data more reasonably follow a logarithmic-normal distribution than an arithmetic-normal distribution. Using a technique described by Leidel et al [1977] percent of samples falling within given values were plotted on logarithmic probability paper (Fig. 1). If these plotted points approximated a straight line, the assumption of a logarithmic-normal distribution would be satisfied. In all cases, the data were reasonably close to a straight line. Once plotted, the 50% value was identified, which is by definition the geometric mean; the 84% value on the chart, divided by the 50% value, produces the geometric standard deviation.

Thus, the *estimates* of geometric means and geometric standard deviations were made. The logarithm of the geometric mean and geometric standard deviation are the only parameters necessary to describe the distribution from which they were derived. For each set of data, a logarithmic-normal distribution was generated by computer. Antilogarithms of the logarithmic-normal distribution values were computed. These arithmetic values were used to estimate an arithmetic mean and standard deviation. Such estimates of the above statistical parameters are influenced by the analytical limit of detection. The parameters are biased upward as the limit of detection increases, ie, data with a limit of detection of 0.5 ppm would be biased higher than data where the limit of detection is 0.1 ppm.

Since some operations have a large number of samples and other operations have a small number of samples, overall industry averages may be unduly influenced by those highly sampled operations. An exception was the estimate of the United States composite, which consisted of the arithmetic average of the composite percent by range for the seven reporting organizations.

ASSUMPTIONS AND LIMITATIONS

For purposes of this presentation, it was assumed that the collection and analytical methods used by the contributors were reasonably accurate. Since most



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CATEGORY DESCRIPTIONS

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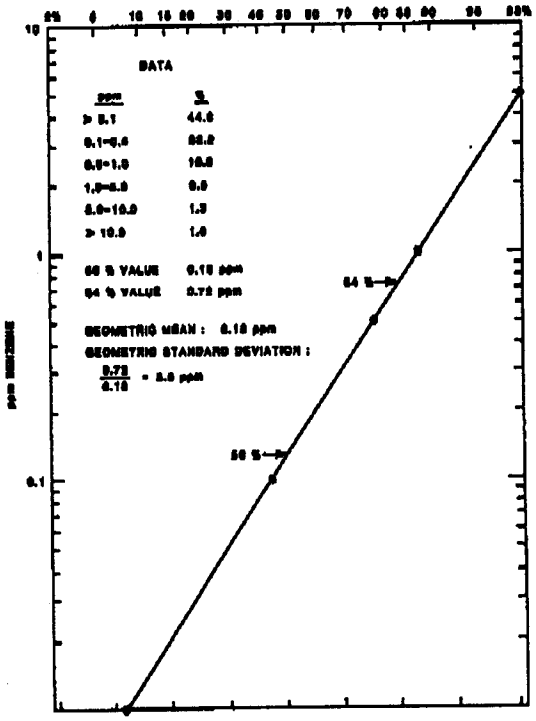

Fig. 1. Technique for estimating geometric means and geometric standard deviations.

industrial hygienists tend to do more sampling around problem areas, these data may not always be a true reflection of the various workplace environs. Nonetheless, this is the best composite available and is probably a fair representation.

These data do not lend themselves to explicit analysis of the reasons some findings were high and others were low. Such specific answers rest in the hands of the firms or organization industrial hygienists having firsthand knowledge about the circumstances surrounding the events of the individual exposure experience in question.

CATEGORY DESCRIPTIONS

Responding companies through API were requested to provide data according to pure benzene and benzene-containing process streams or products—thus, the two descriptors of "benzene" and "other." The "other" would be benzene-containing streams or products such as gasoline. The "mixed" category was added when it was determined that some companies did not or could not separate their sampling results by pure benzene and benzene-containing streams or products. It is believed that the results for "rail car," "truck," and "ship/barge" categories are probably loading operations. The general category of "other" was intended as a "catchall," but the people who compiled the API data feel that most of the samples reflect laboratory operations. Similar detail was not provided by other trade associations. As will be seen later, data on refining operations were available from API, OSHA, and NIOSH;

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petrochemical operations from API and CMA; and loading operations from API and CMA.

FINDINGS

Tables I–VI summarize the percent distribution of exposure to benzene within the various ppm ranges. In addition, these data have been expressed in terms of their estimated statistical parameters.

Nationally (Table I), the collective data representing in excess of 38,000 TWA samples produced an estimated arithmetic mean value of 0.64 ppm and an estimated geometric mean of 0.1 ppm. Eighty-seven percent of all the samples were less than 1.0 ppm. Eleven and four-tenths percent were between 1 and 10 ppm and 1.6% were greater than 10 ppm. In keeping with the belief that the geometric mean value is generally more depictive of the exposure experience, subsequent characterization of our findings will focus on the geometric mean values. The chemical manufacturing industry was seen to have the highest geometric mean value (0.39 ppm). Since no data were reported for less than 0.1 ppm, this value may be biased high. The OSHA value of 0.33 ppm, although relatively high compared to the balance of reporting organizations, may be that high as a product of the small sample size (189 samples) and high variability between the various firms subject to their evaluation.

A review of the petroleum industry data in Table II indicates that the petrochemical operations and bulk transfer of benzene and benzene-containing materials offered the highest opportunity for significant exposure. It should be noted that, in the case of the rail car data, the reporting company advised that respiratory protection was routinely provided. Hence, the implication of exposure is really not as great as it would appear. Employers who have reasons for concern usually provide respiratory protection, and such may be the case in other operations where elevated sampling results were reported.

The benzol plants (Table III), as reported for the iron and steel industry, would appear to offer that industry's greatest opportunity for significant exposure. Nonetheless, the exposure levels are relatively low (2.2 ppm), with an estimated geometric standard deviation of 2.3 ppm. It is noteworthy to observe that all of the coke oven data (2,065) were at or below 0.5 ppm.

The chemical industry data (Table IV) indicated that barge loading, as also shown by the API data, offered the greater opportunity for significant exposure, with an estimated geometric mean of 2 ppm and an estimated geometric standard deviation of 1.7 ppm.

The data for the rubber industry are low (Table V), and based on these data there are no operations where appreciable benzene exposure potential exists.

The OSHA and NIOSH sampling data for refining contained relatively few samples from which statistics were derived. Approximately 28% of their findings were above 1 ppm. The explanation for this may be that those agencies tend to respond to complaints or problems, and it is not their function to conduct facility-wide surveys. Examination of Table VI emphasizes that there is a great deal of variability in the data acquired by OSHA and NIOSH. In a similar vein, we again see a wide variability in the NIOSH data (20 samples) for petrochemical operations (Table VI).

TABLE I. U.S. Benzene Exposure Profile

	Estimated geometric	Estimated	Estimated arithmetic

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Description	No. of samples	ppm (%)						Estimated geometric mean (ppm)	Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
		<0.1	0.1–0.5	0.5–1.0	1.0–5.0	5–10	>10				
American Petroleum Institute	28,561	63.5	25.6	5.1	4.5	0.6	0.7	0.05	6.8	0.29	1.1
National Institute of Occupational Safety and Health	262	62.2	20.2	6.5	8.8	0.8	1.5	0.05	10.4	0.65	3.7
Occupational Safety and Health Administration	189	27.4	28.4	15.2	18.4	5.8	4.8	0.33	8.5	2.87	13.6
National Print and Coating Association	1,261	81.4	16.1	1.6	0.9	0.0	0.0	0.02	5.0	0.07	0.2
Chemical Manufacturers Association	2,448		77.1	→	20.6	2.3	0.0	0.39	3.6	0.87	1.6
American Iron and Steel Institute	3,208		77.9	9.6	10.4	1.7	0.4	0.13	6.0	0.61	2.0
Rubber Manufacturers Association	3,523	52.5	38.3	6.9	2.2	0.1	0.0	0.10	3.3	0.20	0.3
United States	38,317		77.8	9.8	9.3	1.5	1.6	0.10	7.2	0.64	2.5

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TABLE II. Petroleum Industry Benzene Exposure Profile

Description	No. of samples	ppm (%) <0.1	0.1–0.5	0.5–1.0	1.0–5.0	5–10	>10	Estimated geometric mean (ppm)	Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
Other	191	84.4	12.0	1.0	1.6	0.0	1.0	0.01	9.0	0.10	0.5
Retail service stations	1,478	85.6	12.0	1.5	0.7	0.1	0.1	0.02	5.4	0.06	0.2
Exploration/production	3,016	80.0	16.8	1.7	1.2	0.1	0.2	0.03	4.0	0.08	0.2
Pipeline	622	66.9	24.4	3.5	4.7	0.3	0.2	0.05	6.7	0.25	0.9
Trucks benzene mixed	1,356	68.4	23.1	5.3	2.9	0.1	0.2	0.05	4.9	0.17	0.4
Refining	14,824	64.6	26.1	4.6	3.8	0.5	0.4	0.05	5.7	0.22	0.7
Rail car other	19	63.2	26.2	5.3	5.3	0.0	0.0	0.06	5.7	0.26	0.8
Rail car mixed	674	58.5	28.3	7.6	4.9	0.4	0.3	0.06	5.2	0.28	0.8
Marketing terminal trucks	1,452	57.8	32.8	5.3	3.7	0.3	0.1	0.06	4.1	0.21	0.4
Ship/barge benzene mixed	63	61.9	4.8	4.8	19.0	3.2	6.3	0.09	20.0	5.10	49.6
Ship/barge other	457	44.8	30.9	7.4	12.7	2.2	2.0	0.12	9.2	1.22	6.2
Petrochemical	4,165	44.6	33.2	10.0	9.9	1.3	1.0	0.13	5.5	0.52	1.6
Trucks benzene	91	12.1	69.2	9.9	2.2	2.2	4.4	0.23	6.1	1.10	3.7
Ship/barge benzene	90	16.7	17.7	13.3	25.7	8.9	17.7	1.30	9.2	13.2	67.4
Rail car benzene	63	9.6	7.8	6.3	7.9	7.9	60.5	26.0	38.5	Very large	

TABL

Descri							Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
By-pr									
Benzol plant	113	6.2	5.3	74.3	13.2	1.0	2.20	2.3	3.11	3.0
Chemical laboratory	133	40.6	40.6	18.8	0.0	0.0	0.56	1.8	0.67	1.2

Petrochemical	4,165	44.6	33.2	10.0	9.9	1.3	1.0	0.13	5.5	0.52	1.6
Trucks benzene	91	12.1	69.2	9.9	2.2	2.2	4.4	0.23	6.1	1.10	3.7
Ship/barge benzene	90	16.7	17.7	13.3	25.7	8.9	17.7	1.30	9.2	13.2	67.4
Rail car benzene	63	9.6	7.8	6.3	7.9	7.9	60.5	26.0	38.5	Very large	

TABLE III. American Iron and Steel Industry Benzene Exposure Profile

Description	No. of employees	ppm (%)						Estimated geometric mean (ppm)	Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
		<0.1	0.1–0.5	0.5–1.0	1.0–5.0	5–10	>10				
By-product plant	897		41.6	27.8	25.0	4.3	1.3	0.65	3.4	1.35	2.2
Benzol plant	113		6.2	5.3	74.3	13.2	1.0	2.20	2.3	3.11	3.0
Chemical laboratory	133		40.6	40.6	18.8	0.0	0.0	0.56	1.8	0.67	4.2
Coke oven	2,065		100.0	0.0	0.0	0.0	0.0	N.A.	N.A.	N.A.	N.A.

TABLE IV. Chemical Manufacturing Industry Benzene Exposure Profile

Description	No. of employees	ppm (%)						Estimated geometric mean (ppm)	Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
		<0.1	0.1–0.5	0.5–1.0	1.0–5.0	5–10	>10				
Barge loading	36		8.3	→	88.9	2.8		2.00	1.7	2.31	1.3
Rail loading	278		87.1	→	11.9	1.0		0.19	4.2	0.52	1.1
Truck loading	426		90.1	→	9.4	0.5		0.09	6.0	0.42	1.4
Petrochemical	1,708		73.7	→	23.4	2.9		0.45	3.6	1.00	1.8

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TABLE V. Rubber Manufacturers Association Benzene Exposure Profile

Description	No. of samples	ppm (%) <0.1	0.1–0.5	0.5–1.0	1.0–5.0	5–10	>10	Estimated geometric mean (ppm)	Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
Bead dip operator	64	29.8	64.0	3.1	3.1	0	0	0.14	2.6	0.22	0.3
Cure/finisher	96	67.6	24.0	2.1	6.3	0	0	0.04	6.3	0.20	0.7
Calender operator	33	45.4	42.4	6.1	6.1	0	0	0.12	3.5	0.26	0.4
Spray operator	183	37.7	51.4	9.3	1.6	0	0	0.16	2.4	0.23	0.2
Cement house operator	281	43.0	45.9	9.3	1.8	0	0	0.12	3.0	0.22	0.3
Tire repair	167	74.2	23.4	2.4	0	0	0	0.04	3.6	0.09	0.2
Casing assembly	139	66.9	26.6	3.6	2.9	0	0	0.05	4.8	0.16	0.4
Tire builder	1,184	40.5	46.5	10.0	3.0	0	0	0.15	2.8	0.25	0.3
Tuber	433	52.1	35.6	7.4	4.4	0.5	0	0.09	4.3	0.25	0.6
Extruder	43	33.6	58.1	9.3	0	0	0	0.15	2.5	0.23	0.2
Miscellaneous	897	69.0	27.4	3.3	0.3	0	0	0.05	3.5	0.11	0.2
Banbury operator	3	100.0	0	0	0	0	0	N.A.	N.A.	N.A.	N.A.

TABLE VI. U.S. Agency Profile of Benzene Exposures

Description	No. of samples	ppm (%) <0.1	0.1–0.5	0.5–1.0	1.0–5.0	5–10	>10	Estimated geometric mean (ppm)	Estimated geometric standard deviation (ppm)	Estimated arithmetic mean (ppm)	Estimated arithmetic standard deviation (ppm)
Occupational Safety and Health Administration Refining	66	9.1	40.9	21.2	19.7	3.0	6.1	0.50	6.0	9.33	30.5
National Institute of Occupational Safety and Health Refining	74	39.1	29.7	14.9	13.5	1.4	1.4	0.18	6.1	0.87	2.9
National Institute of Occupational Safety and Health Petrochemical	20	30.0	40.0	5.0	10.0	0.0	15.0	0.21	25.7	10.51	98.6

The apparent lack of hig
have relevancy to the absence
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CONCLUSIONS

1. The TWA data assem
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2. Some variability betw
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3. The United States ind
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4. These data may have
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National Institute of Occupational Safety and Health Petrochemical	20	30.0	40.0	5.0	10.0	0.0	15.0	0.21	25.7	10.51	98.6

The apparent lack of high TWA exposure data during this reporting period may have relevancy to the absence of reported benzene-induced leukemias among workers having initial exposure since 1977. All recent epidemiological studies within the petroleum industry known to these authors involve cohorts having their exposure experience, hence leukemia, *prior* to 1978 [Wen et al, 1981, 1983; Decoufle and Blatner, 1982; Hanis et al, 1982; Cole, 1983; Exxon Corporation, 1983; Gulf Oil Corporation, 1983; Texaco, 1983]. Likewise, it was not possible to identify any individual case or anecdotal reports in the literature since 1977 involving benzene-induced leukemia. Considering the latency period of this disease, however, continued follow-up on recent retrospective epidemiological studies is still in order.

CONCLUSIONS

1. The TWA data assembled for this report encompassing the years 1978–1983 indicate that on a national basis 87.6% were below 1 ppm, and 98.4% were below 10 ppm.

2. Some variability between industries occurred as expected, with the highest exposure experience seen in those operations involving the bulk transfer of benzene, per se, and benzol plant operations.

3. The United States industry continues to operate well below OSHA standard and, as is typical, few employers will operate in close proximity to any specified standard.

4. These data may have relevancy to the absence of reported benzene-induced leukemias among workers having initial exposure since 1977.

5. Although the geometric mean exposure experience encountered across U.S. industries is clearly below 10 ppm (range 0.02–0.39 ppm), closer examination indicates that loading operations and benzol plant operations could have difficulty uniformly operating within a significantly reduced PEL under current practices.

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