Retrospective Mortality and Medical Surveillance Studies of Workers in Benzene Areas of Refineries

Shan P. Twi, Ph.D.; C. P. Wen, M.D.; Nancy S. Weiss, M.P.H.; Otto Wong, Sc.D.; William A. McClellan, M.D.; and Roy L. Gibson, M.D.

The mortality and health experiences of refinery workers employed in benzene processes or operations are described. A retrospective cohort mortality study of benzene workers employed from 1952 to 1978 revealed no excess in overall general mortality or in cancer mortality compared either with the experience of the U.S. general population or with that of an internal control group. Ascertainment of vital status was accomplished for 99% of the cohort. Recent industrial hygiene data that included 1,394 personal samples indicated that 84% of all benzene exposures were less than 1 part per million (ppm), with a median exposure of 0.14 ppm for the refinery workers, and 0.53 ppm for those in the benzene-related units. Among these workers, no deaths from leukemia were observed. A medical surveillance program for benzene workers is also described, with special emphasis on the effectiveness of laboratory screening. Evaluation of data for a 21-year period showed no significant changes in the blood indices of the workers as a group. The limited value of establishing screening guidelines without the support of epidemiological studies is discussed.

The potential effects on workers of chronic benzene exposure is a subject of increasing attention.[1,2] Animal and human studies have focused on potential insults by benzene to the hematopoietic system. Numerous case reports and several epidemiological studies have attempted to establish the leukemogenicity of benzene.[3-8] The results, however, have not been consistent, and data on human health effects at the exposure level of current operations of petrochemical industries are limited. Due to the ubiquitous nature of benzene in many industries, the control of its hazards will continue to be a complex issue.[9]

This study examines the mortality and health experiences of refinery workers employed in benzene processes or operations. Of all the employees at the refinery, the workers exceeding seven hours; *partial* samples are those with sample exposure and would be the ones most likely to demonstrate adverse mortality and health patterns. In addition to exposures to benzene, these workers have also had potential exposures to other chemicals found in a typical refinery setting.

This report is divided into two parts. The first part describes a retrospective mortality study of benzene workers employed from 1952 to 1978 at a Texas refinery. The second part is an evaluation of a 21-year medical surveillance system for benzene workers in place since 1959 at the same refinery.

I. RETROSPECTIVE MORTALITY STUDY OF BENZENE WORKERS

Materials and Methods

Definition of the Benzene Cohort — The study includes all male workers ever employed at a large Texas refinery from Sept. 15, 1952. to Jan. 1, 1978 (regardless of the length of their employment) who worked directly on the benzene, ethylene, aromatic distillate hydrogenation (ADH) or cumene units which are the principal petrochemical units in the refinery. Maintenance workers assigned on a regular basis to the benzene-related units, utility men, and laborers assigned to these units were included in the cohort. However, maintenance workers who were assigned to benzene units on an irregular basis were not included.

The ethylene unit began operation of Sept. 15, 1952; benzene on Sept. 14, 1959; ADH on May 30, 1962; and cumene on Jan. 5,1970.

Exposure Data — Data of exposure to benzene for the years 1973 through 1982 were examined. Data for the years prior to 1973 were inadequate for assessing the workers' exposure. The personal sampling exposure data for the 10-year period have been compiled for employees from the entire refinery and are shown in Table 1.

Benzene was measured by the silica gel or midget impinger method at an earlier time period and by charcoal tubes later. Data were divided into two categories according to the sampling time. *Full* samples are those with sampling time greater than or equal to four hours, with the majority

From the Gulf Oil Corporation (Ms. Weiss and Drs. Tsai, Wen, McClellan, and Gibson); and Environmental Health Associates, Berkeley, Calif. (Dr. Wong).

Address correspondence to Gulf Oil Corporation, P.O. Box 2100, Houston. TX 77252 (Dr. Wen).

Table 1 — Frequency Distribution of Benzene Exposure for Refinery Workers, 1973-1982			
Benzene Concentration, ppm	Full — No. of Samples (%)	Partial — No. of Samples (%)	Combined — No. of Samples (%)
<0.10	378 (52)	222 (33)	600 (43)
0.1-0.99	270 (37)	301 (46)	574 (41)
1.0-4.99	66 (9)	97 (14)	163 (12)
5.0-9.99	10 (1)	19 (3)	29 (2)
10.0-24.99	1 (0)	12 (2)	13 (1)
>25.0	2 (0)	13 (2)	15 (1)
Total	727 (99)	667 (100)	1,394 (100)

ers in this operation have presumably received the greatest ling time less than four hours or those recorded as partial samples whose data on sampling time were missing. No attempt has been made to adjust the exposure numbers to eight-hour time-weighted averages (TWAs).

The sampling strategy used by industrial hygienists for determining personal exposure has usually been based on representative sampling of various job assignments or worst case sampling on spills or turnaround. Job classifications selected for sampling are usually those in which the highest potential for exposure exists during routine operations. Replications of these job classifications are then sampled to characterize the exposures.

Data Collection — Copies of all personnel records since the refinery operation was started in 1901 were made, and pertinent demographic and work history information were screened according to the cohort definition previously described.

Of the approximately 20,000 employees whose records were collected and screened, 454 have been identified as benzene workers. Data coltected on each cohort member included name, date of birth, race, sex, social securnty number, date of hire, employment status, date of last separation, if any; vital status: date of death for known decedents, and cause of death; and work history. Each work history consisted of a chronological listing of all jobs ever held by the individual and included the dam of job assignment, department, unit and job title.

Standard epidemiologic procedures for ascertaining the vital status of the cohort were followed. They included matching the cohort employees with rosters of current employees and annuitants, matching with death certificate files of company records, obtaining information from the Social Security Administration, and the Texas and Louisiana Departments of Motor Vehicles and a plant follow-up. Death certificates were collected from the vital statistics departments of individual stater for all known decedents. The underlying cause of death was coded by a trained nosologist according to the rules of the International Classification of Diseases (ICD) revision in effect at the time of death and then recoded to the ICD adapted (ICDA) eighth revision.[10]

For analytical purposes, numbers of penon-yean at risk were calculated. The denominator data wen determined from Sept 15, 1952, or from the date of first benzene exposure, whichever was later, to the end of the study period (Jan. 1, 1978) or to the date of death, which ever was earlier. Individuals with unknown vital status were assumed lost to follow-up on the date of termination or on the last data of contact, whichever was later. The number of years contributed by each worker was classified by age, race, and calendar year. The US. national age-sex-race-year-cause-specific mortality rates for five-year time intervals during the study period were! applied to these numbers of person-years to obtain the number of expected deaths from a specific cause. Standardized mortality ratios (SMRs) were computed and their significance testing is based on the assumption of a Poisson distribution for the observed numbers of deaths, utilizing a two-sided test of significance. Part of the analysis was performed using a computer program developed by Monson.[11]

An internal comparison group consisting of a 10% sample of the employees from the same plant who worked during the same periods in operations not related to benzene was selected. The selection guide was social security number and the analysis was based on relative risks determined by using the Mantel-Haenszel procedure.[12]

Results

Table 2 shows the characteristics of the benzene cohort. Of the total cohort of 454 employees, 369 (81%) were white and contributed a combined total of 5,900 person-years. The average age of study subjects at entry into the cohort was approximately 34 years and the average length of follow-up 13 years. The average number of years of benzene-related work (exposure) was 8.0 for the white employes and 4.5 for the nonwhite employees. The cohort is relatively young with only 7.5% (N=34) of the employees found to be deceased. All death certificates were identified and only three employees were lost to follow-up. Thus, the followup was successful for 99.3% of the cohort.

Distributions of the benzene cohort by year of first exposure and duration of exposure are shown in Tables 3 and 4, respectively. One-half of the cohort began work in benzene areas before 1965 and almost 80% had exposum lasting one year or longer.

Table 2 — Benzene Cohort Statistics Sept. 15, 1952 to Jan. 1, 1971			
Characteristics	White	Nonwhite	Total
Na studied	369	85	454
(%)	(81)	(19)	
Person-years of observation	5,000.7	894.3	5,900
(%)	(85)	(15)	
Average age at entry	33.0	37.3	33.8
Average follow-up, yr	13.6	10.5	13.0
Average exporun, yr	8.0	4.5	7.4
No. alin	340	77	417
No. dad	26	8	34
Death certificate unavailable	0	0	0
No. lost to followup	3	0	3
(%)	(0.8)	...	(0.7)

Table 3 — Distribution of Cohort by Year of First Exposure		
Year of First Exposure	No. (%)	
1952-1954	61 (13.4)	
1955-1959	102 (22.5)	(50.2)
1960-1964	65 (14.3)	
1965-1969	73 (16.1)	
1970-1974	104 (22.9)	
1975-1977	49 (10.8)	
Tod	454 (100.0)	

by	
Length of Exposure, yr	No. (%)
<1	95 (20.9)
1-4	145 (31.9)
5-9	77 (17.0)
10-14	52 (11.4)
15.19	47 (10.4)
>20	38 (8.4)
Tod	454 (100.0)

The total number of sampler of personal exposure to benzene obtained was 1,718. Averages were taken when there were two or more samples from the same individuals on the same dav, resulting in 1,394 samples for analysis, as shown in Table 1. For 89% of the full samples and 79% of the partial samples exposures were less than 1 part per million (ppm) benzene. For 10% of the full samples and 17% of the partial samples exposures were between 1 and 10 ppm. In addition, for 4% of the partial samples exposures exceeded 10 ppm.

Table 5 shows benzene exposures by selected units. As expected, the median benzene exposure was highest among those assigned to the cumene and benzene and cyclohexane units. This was followed by amine, waste water treatment, pump house, laboratory, ethylene, ADH unit, and docks, in descending order based on full samples. For partial samples, the order was cumene, benzene and cyclohexane, ethylene, docks, ADH unit, laboratory, amine, waste water treatment, and pump house. Since the study design was limited to those working in the benzene and cyclohexane, cumene, ADH, and ethylene units, these units were grouped in Table 6 as "benzene-related units" while the remaining units listed in Tabk 5 were classified as "other benzene areas." All of the remaining samples taken in the refinery were classified as "all othm" The exposum from the benzene-related units were the highest with a median of 0.53 ppm, followed by those from other benzene areas with 0.24 ppm. Exposures from all others were clearly the lowest with a median of 0.07 ppm.

Table 7 presents the SMRs for selected causes of death for all males (white and nonwhite combined). The cohort as a whde showed a favorable overall mortality experience. There were a total of 34 deaths with 58.69 deaths expected. The expected numbers of deaths were calculated far white and nonwhite males independently based on the US. white and nonwhite male mortality rates and then were added together. The SMR for all causes (0.58) is significantly decreased with $p < .01$. The mortality for arteriosclerotic heart disease showed a similar significant deficit (SMR=0.46). The number of cancer deaths (10) was slightly smaller than expected (11.53; SMR=0.87). There were no cases of leukemia or of cancer of the lymphatic system.

Excesses were seen for cancers of the stomach, large intestine and brain, each with two deaths. Cancer of the buccal cavity and pharynx and cancer of the larynx were also increased, each with one death. The numbers were too small to permit any conclusion and chance variation could explain the excesses. However, this points out the need for continuation of the surveillance of benzene workers to verify the significance, or the lack of significance, of these observations.

Table 8 shows SMRs for those who worked one year or more in the benzene areas. The total number of the cohort decreased from 454 to 359. The results an similar to those shown in Table 7. The total number of cancer deaths decreased from 10 to four and the SMR for cancer changed from 0.87 to 0.49.

Table 5 — Benzene Exposure Concentrations (ppm) by Selected Units*

Unit	Full N	Full Median	Full Mean ± SD	Full GM ± GSD	Partial N	Partial Median	Partial Mean ± SD	Partial GM ± GSD
Benzene and cyclohexane	85	0.79	1.34 ± 1.39	0.80 ± 2.96	57	1.25	5.56 ± 8.74	1.44 ± 6.48
Cumene	13	1.18	6.10 ± 10.89	1.37: 6.58	38	1.60	5.96 ± 14.42	1.85 ± 3.29
ADH	18	0.06	0.33 ± 1.01	0.04 ± 9.94	21	0.59	0.74 ± 0.70	0.08 ± 16.75
Ethylene	32	0.09	0.11 ± 0.07	0.07 ± 2.73	80	0.85	0.27 ± 0.38	0.11 ± 3.75
Pump house No. 11	57	0.18	0.55 ± 1.12	0.12 ± 15.52	26	0.04	7.45 ± 23.79	0.12 ± 13.26
Docks	32	0.05	0.10 ± 0.14	0.06 ± 2.35	63	a75	3.65 ± 9.16	0.55 ± 9.96
Amine	9	a75	1.25 ± 1.24	0.64 ± 4.12	5	0.41	0.49 ± 0.29	0.40: 2.11
Laboratory	38	0.14	0.92 ± 3.92	0.06 ± 14.10	Sa	0.46	2.05 ± 7.09	0.49 ± 3.93
Wastewater treatment	55	0.54	1.16 ± 2.20	0.37 ± 5.04	4	0.15	0.41 ± 0.34	0.28 ± 2.88

* SO indicates standard deviation; GM, geometric mean; GSO, geometric standard deviation

Table 6 – Comparison of Benzene-Related Units With Others*

Benzene Concentrations	Benzene-Related Units, No. (%)		Other Benzene Areas, No. (%)		All Others, No. (%)	
	Full	Partial	Full	Partial	Full	Partial
<.1 ppm	30 (20.3)	51 (26.0)	74 (38.7)	32 (20.5)	264 (68.0)	139 (44.1)
.1-0.99 ppm	76 (51.4)	12 (38.7)	91 (47.6)	79 (50.6)	113 (29.1)	153 (48.6)
1.0-4.99 ppm	38625.7)	51 (26.0)	19 (9.9)	26 (16.7)	9 (2.6)	21 (6.7)
5.0-9.99 ppm	2 (1.4)	7 (3.6)	6 (3.1)	10 (6.4)	2 (0.5)	110.31
10.0-24.99 ppm	...	a (4.1)	1 (0.5)	3 (1.9)	...	1 (0.3)
>25.0 ppm	2 (1.4)	7 (3.6)	...	6 (3.8)	...	...
Total	148	196	191	158	388	315
Median	0.35	0.61	0.17	0.46	0.04	0.1 1
Mean	1.38	2.96	0.76	3.51	a19	0.35
SD	3.66	8.29	2.22	12.13	0.57	1.08
GM	0.35	0.40	0.14	0.40	0.06	0.10
GSO	6.43	9.20	8.52	1.78	4.19	4.79

* SO indicates standard deviation; GY, geometric mean; GSD. geometric standard deviation

Discussion

Analysis of overall mortality for the benzene cohort revealed no significant excesses. In general, mortality from all causes and from diseases of the circulatory system was significantly lower than expected based on the experience of a comparable group of US. males. Thus, benzene workers in this study demonstrated a healthy worker effect13 similar to that seen among other employed groups.

As part of the original design, an internal comparison group was selected (using social security number as a selection guide) for further validation of results. This comparison group included 10% of the worken who were employed in the same plant during the same time period in opetations not related to benzene. There were 823 people in the comparison group, approximately twice as many as in the study cohort. Table 9 presents the relative risks for the study co-

Table 7 – SMRs for Selected Causes of Deaths of All Male Subjects (N=454)

Cause of Death (ICDA 8th Code No.)	Observed Deaths	Expected Deaths	SMR	95% Confidence Limits	
				Lower	Upper
All causes	34	58.69	0.58*	0.40	0.8 1
All cancers (140-209)	10	11.53	0.87	0.42	1.60
Cancer of buccal cavity and pharynx (140-149)	1	a4 3	2.33	0.03	1294
Cancer of digestive system (150-159)	4	3.16	1.27	0.34	3.24
Cancer of stomach (151)	2	0.62	3.23	0.36	11.65
Cancer of large intestine (153)	2	0.89	2.25	0.25	8.1 1
Cancer of respiratory system (160.1633	3	4.12	a7 3	0.15	2 1 3
Cancer of larynx (161)	1	0.19	5.26	0.07	29.28
Cancer of lung (162-163)	2	3.88	0.52	0.06	1.86
Cancer and tumor of brain (191-192, 225, 238)	2	0.47	4.26	0.48	15.36
All lymphopoietic cancer (200-209)	0	1.12	0.00	0.00	3.28
Leukemia and aleukemia (204-207)	0	0.42	0.00	0.00	8.73
Diseases of circulatory system (390-458)	15	27.89	0.54†	0.30	0.89
Arteriosclerotic heart disease (410-413)	9	19.49	0.48†	0.21	0.88
Cerebrovascular disease (430-438)	2	X70	0.54	0.06	1.95
Nonmalignant respiratory disease (460-519)	1	3.14	0.32	0.00	1.77
Pneumonia (480-486)	1	1.26	0.79	0.01	4.42
Diseases of digestive system (520-577)	1	3.37	0.30	0.00	1.65
Accidents, poisonings and violence (E800-E999)	5	7.52	0.66	0.21	1.55
Accidents (800-949)	4	4.72	0.85	0.23	2.17

Table 8 — SMRs for Selected Causes of Deaths of All Male Subjects Working One Year or More in Benzene Areas (N=359)

Cause of Death (ICDA 8th Code No.)	Observed Deaths	Expected Deaths	SMR	95% Confidence Limits Lower	95% Confidence Limits Upper
All causes	22	40.66	0.54*	0.34	0.82
All cancers (140-209)	4	818	0.49	0.13	1.25
Cancer of buccal cavity and pharynx (140-149)	1	0.30	3.33	0.04	18.54
Cancer of digestive system (150-159)	2	224	0.89	0.10	3.22
Cancer of stomach (151)	1	0.43	2.32	0.03	12.94
Cancer of large intestine (153)	1	0.65	1.54	0.02	8.56
Cancer of respiratory system (160-163)	1	295	0.34	0.00	1.89
Cancer of lung (162-163)	1	2.79	0.36	0.00	1.99
Cancer and tumor of brain (191-192, 225, 238)	1	0.31	3.23	0.04	1735
All lymphopoietic cancer (200-209)	0	0.78	0.00	0.00	4.70
Leukemia and aleukemia (204-207)	0	0.29	0.00	0.00	1265
Diseases of circulatory system (390-458)	12	19.87	0.60	0.31	1.08
Arteriosclerotic heart disease (410-413)	9	14.13	0.64	0.29	1.21
Cerebrovascular disease (430-438)	2	255	0.78	0.09	283
Nonmalignant respiratory disease (460-519)	0	224	0.00	0.00	1.64
Diseases of digestive system (520-577)	1	2.29	0.44	0.01	243
Accidents, poisonings and violence (E800-E999)	4	4.63	0.86	an	2.21
Accidents (800-949)	4	2.90	1.38	0.37	3.53

* Statistically significant at .01 level

hort and the comparison group for all causes and for cancer of ail sites. The relative risks are based on the adapted Mantel-Haenszel procedure for a cohort study,[12] and are adjusted for age and race. The relative risk for all causes was decreased (0.90) while the increase in relative risk for all cancer (1.31) was not significant at the .05 level. This gives further support to the finding that the study cohort did not show any increased risk, compared with either the U.S. general population or the general refinery employees.

The levels of benzene exposure monitored between 1973 and 1982 from workers in this refinery were quite variable, although most of them were low and the median exposure was 0.14 ppm, for the refinery workers, and 0.53 ppm for those in the benzene-related units. More than 84% of the samples showed an exposure of less than 1 ppm benzene. Of those samples showing exposum greater than 1 ppm benzene, two thirds, 144/220, were partial samples. Only three full samples from a total of 727 samples exceeded the 10-ppm limit. It should be pointed out again that full samples had a sampling time of fourhours up to eight hours.

Of particular importance is that no leukemia deaths were observed for those with greatest exposure to benzene in this refinery. Even if we were to assume that one leukemia death was observed, the SMR for all lymphopoietic cancer would be equal to 0.89 with a 95% confidence interval of 0.01 to 4.497. Since no leukemia deaths were observed, an SMR greater than 3.30 is highly unlikely despite the relatively small sample size of this study.

This result is not compatible with the report by the National Institute for Occupational Safety and Health (NIOSH) of an SMR for leukemia of 5.60 among workers manufacturing rubber hydrochloride.' The two studies wen similar in aspects such as methodology and time periods of observation. In the NIOSH study the sample sizes were 748 for the total cohort and 311 for those exposed one year or more, compared with 454 for the total cohort and 359 for those exposed one year or more in this study. The benzene exposure was interpreted in the NIOSH study as falling mostly "within the limits considered (legally) permissible at the time of exposure" and likewise in this study. Benzene exposure of the rubber worken appears to have been much higher with median exposures in eight different units between 3.4 and 9.4 ppm from 1973 through 1976, a period for which comparable exposure

Table 9 — Relative Risks for Death From All Causes and From Cancer of All Sites for the Study Cohort and the Comparison Group

Cause of Death	Study (N=454)	Comparison (N=823)	Relative Risk	x^{2*}	P Value
All causes	34	160	0.30	0.34	028
Cancer of all sites	10	30	1.31	0.54	0.23
Leukemia and lymphopoietic cancer	0	5	...	...	...

* Mantel-Haenszel x^2 with 1*df*

data were available from refinery workers exposed to benzene. It should be noted that the majority (58%) of the NIOSH study subjects had been exposed for less than one year. Exposure data in both studies were extremely limited for the earlier years.

Through analyses of these exposum data, five additional units or areas in the refinery have been identified as yielding the next highest level of exposure. They are the pump house, waste water treatment unit, docks, laboratory and amine unit. Studies in the future would be more complete if the benzene cohort also included these areas or units, even though benzene exposures in these areas were very much lower.

In summary, examination of the mortality experience of benzene workers (1952-1978) showed a favorable overall mortality (SMR = 0.58). The mortality risk from all causes from all cancer or from lymphopoietic cancer is not increased.

II. MEDICAL SURVEILLANCE PROGRAM OF BENZENE WORKERS

Concomitant with the effort to minimize workers' benzene exposure, their health is closely monitored. The importance of a medical surveillance program is generally recognized. However, screening procedures vary and results are difficult to interpret. Of particular controversy is the utility of blood screening (hematology and chemistry) for early detection of blood dyscrasia. In addition to leukemia, blood disorders such as pancytopenia or aplastic anemia have been associated with benzene exposure. Greenburg et al[14] in 1939 and Aksoy et al[15] in 1971 found significant abnormalities in hematological results of workers with high levels of exposure to benzene (recorded exporum up to 210 ppm). Townsend et al[16] studied the health examination findings of 282 men occupationally exposed to benzene and found a slight decrease in mean total bilirubin and red blood cell (RBC) values as compared with a control group, but these changes were riot regarded as clinically significant. Fishbeck et al[17] found no persistent hematological effects except for a slight reduction in hemoglobin and an increase in the mean corpuscular volume (MCV) of 10 employees with chronic benzene exposure for several years exceeding the 25 ppm eight-hour TWA.

The remainder of this report presents data from a group of refinery worken who are employed in benzene areas and who have been under medical surveillance since 1959. Blood screening has been conducted on there workers for a period of 21 years, from 1959 through 1979.

Subjects and Methods of Study

As part of the medical surveillance program of morbidity and mortality at the refinery, beginning in 1959, blood tests were performed on each benzene worker up to four times a year. These tests included hemoglobin, hematocrit, white blood cell count with differential, platelet count, bleeding and dotting times. Frequency of examination was later reduced to once a year in the early 1960s. With the advent of the autoanalyzer and the Coulter counter, a 12-panel automated blood chemistry (SMA 12) or SMAC and a complete blood count wen added in the early 1970s.

Each year benzene workers were defined by the supervisor for each of the units and included workers assigned for a certain period of time to one of the following units: benzene, ADH, ethylene, polymerization, cumene, pump houses, loading shop and docks, and barges of the bulk oil department. The benzene workers included worken from units other than those mentioned in part I; time periods overlapped (from 1952 through 1978 for part 1 and from 1959 through 1979 for put 2).

Outcome of Workers in the Medical Surveillance Program

Results of the hematology and the blood chemistry profiles are presented in Tables 10 and 11, respectively, in terms of the mean, the standard deviation, the value, at 5th and 95th percentiles, and the number of examinations recorded and analyzed. Approximately 1,400 tests of hematology and 900 tests of blood chemistry were conducted. As a group, the workers showed values within normal limits; no tendency of pancytopenia (aplastic anemia), bleeding or clotting deficiency, judged from the mean and the 5th and 95th percentile values in the hematology data profile (Table 10), was seen. Results of the blood chemistry profile were also generally within normal limits, including bilirubin, which should have increased if hemolytic anemia occurred or liver function was impaired (Table 11). A small portion of the value) falling within the lower or upper 5% might have been considered clinically abnormal, but, when tests were repeated, the results usually returned to normal and were therefore judged to be clinically normal. Most of these discrepancies may have resulted from individual and laboratory variations. Only in one of 303 workers did repeated blood tests lead to an early diagnosis of multiple myeloma

Among these 303 employees who had received medical surveillance a total of 11 deaths had occurred as of the end of 1979, whereas 21.46 deaths were expected (SMR = 0.51). Causes of these 11 deaths included: coronary heart disease (seven observed; 9.68 expected); cirrhosis of the liver (one observed; 0.90 expected); "natural causes" (one observed); and cancer (two observed; 4.42 expected). The cancer deaths were from malignant melanoma and multiple myeloma. As of 1979, none of the reported deaths had been ascribed to leukemia nor had any living employee developed leukemia.

Discussion

The medical surveillance system is important for multiple reasons. Among them are creation of baseline data for future comparisons; provision of trend analysis of groups or subgroups; early detection of adverse health effects; provision of medical benefits to the employee; and increased awareness emphasizing health maintenance and promotion.

From the clinical standpoint, early detection of Eversible health effects is probably the mort important justification for a medical surveillance program. However, the experience of the program described in this report suggests the need for establishing different interpretation criteria of screening for adverse effects of benzene exposures.

As in every biological phenomenon, the screening results varied within expected ranges from individual to individual

Table 10 – Summary of Hematology Data Profile*

Hematology	Mean	SD	Values at 5th%	Values at 95th%	No. of Examinations
WBC, $10^3/\mu l$ blood	6,952	1,891	4,300	10,300	1,404
Polymorphonuclear	4,177	1,458	2,112	6.588	1,396
Lymphocyte	2,406	782	1,350	3.860	1,398
Hemoglobin, g/ml blood	14.8	1.1	13.0	16.7	1,404
Hematocrit, %	44.4	3.7	39.0	50.4	1,399
RBC, $10^6/\mu l$ of blood	5.0	0.4	4.4	5.6	602
Platelet, $10^3/\mu l$ blood	293.0	97.0	t60.0	459.0	1,085
Bleeding time, min	1.64	0.80	0.62	3.0	1,001
Clotting time, min	6.00	1.00	3.38	6.58	1,002

Table 11 – Summary of Blood Chemistry Profile*

Blood Chemistry	Mean	SD	Values at 5%	Values at 95%	No. of Examinations
Glucose, mg/dl	94.1	17.4	73	118	903
BUN. mg/dl	15.1	4.2	10	21	902
Uric acid, mg/dl	6.3	1.3	4.5	8.4	902
Calcium. mg/dl	9.9	0.5	9.1	10.5	895
Phosphorus, mg/dl	3.3	a5	2.4	4.1	895
Cholesterol, mg/dl	207	41	144	275	897
Triglyceride, mg/dl	134	a4	48	287	266
SGOT. units	30.6	15.2	14	54	902
SGPT, units	31.1	23.1	9	56	272
Bilirubin total, mg/dl	0.65	027	0.2	1.1	902
Bilirubin direct, mg/dl	0.15	0.13	ai	0.2	245
Bilirubin indirect, mg/dl	0.56	0.32	01	1.0	266
Total Protein. g/dl	7.2	0.5	6.4	7.9	904
Globulin. g/dl	27	0.5	2.0	3.2	270
Albumin. g/dl	4.4	0.4	3.8	4.9	903

* Data have been collected between 1970 and 1979: the number of examinations on individuals varies

and within individuals from year to year. These variations have been intensely confounded by different laboratory standard practices and advancements throughout the years. In the past, such variations have been handled on an individual basis by the judgment of clinicians. With the advent of computer storage which makes statistical analysis of large sets of biological data possible, the lack of a "healthy population" standard has emerged as an obstacle to an objective analysis. A study by Frederik[18] of approximately 20,000 employees indicated that the usual hematologic normal ranges derived largely from hospital experiences are not applicable to an employed population. Thus, even though in several instances the results may be judged to be marginal or even "abnormal" by hospital standards, they could well be within the "normal" variations. For regulators, this would certainly present difficulties when trying to establish screening guidelines and referral criteria.

It should be realized that the predictive value[19] of each test or of a battery of tests is far from established for marginally abnormal test results.[20] Only when values are overtly abnormal can one conclude that health status may be either compromised or in true jeopardy. In this study, as the result of hematological screening one patient was suspected of and later proved to be suffering from multiple myeloma. Other less serious conditions have also been diagnosed. However, not all early interventions proved to be early enough, including the case of the patient with multiple myeloma

The occupational medical surveillance program should undergo periodic evaluation to define priorities among competing goals and to improve effectiveness and efficiency. This could include activities to determine the predictive value of each screening procedure. Findings should be translated into beneficial actions for the employees, whether such actions are health education for life-style changes, process engineering changes to reduce exposure, or clinical referral and intervention to prevent illness and disability. Screening per se is just one of the many preven-

tive measures that constitute the surveillance program, but guidelines as to its frequency and interpretation should be based on cumulative (long-term) epidemiological results from different screening practices.

Acknowledgment

Irving Tabershaw, M.D., and hb associates conducted the initial phase of part I of the study.

References

1. McMichael AG. Spirtas R, Kupper LL, et al: Solvent exposun and leukemia among rubber workers: An epidemiologic study. J *Occup Med* 17:234-239, 1975.

2. Browning E: Toxicity and Metabolism of Industrial Solvents. New York: Elsevier Pulishing Co, 1965.

3. Vigiani EC: Leukemia associated with benzene exposure. *Ann NY Acad Sci* 271:143-151, 1976.

4. Aksoy M: Leukemia in shoe-workers exposed chronically to benzene, *Blood* 44:837-841, 1974.

5. Infante PF, Rinrky RA. Wagoner JK. et d: Leukemia among workers exposed to benzene. *Lancet* 2: 76-78, 1977.

6. Thorp. JJ: Epidemiologic survey of leukemia in persons potentially exposed to benzene. *J Occup Mcd* 16:375-382, 1974.

7. Ott MG, Townsend JC, Fishbeck WA, et al: Mortality among individuals occupationally exposed to benzene. *Arch Environ Health* 34:3-10, 1978.

8. Rinrky RA, Young RJ, Smith AB. Leukemia in benzene workers. Am *J Ind Med* 2:217-245, 1981.

9. White MC, Infante PF, Walker B. Jr: Occupational exposure to benzene: A review of carcinogenic and related health effects following the U.S. Supreme Court decision. *Am J Ind Med* 1:233-243.1980.

10. Eighth Revision International Classification of Diseases, adapted for use in the United States. DHEW, Public Health Service publication 67-1693. Washington, D.C.: US. Gov't Printing Office, 1967.

11. Monson RR: Analysis of relative survival and proportional mortality. *Comput Biomed* R a 7:325-332, 1974.

12. Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *JNCI* 32:719-748, 1959.

13. Wen CP, Tsai SP, Gibson RL: Anatomy of the healthy worker effect: A critical review. *J Occup Med* 25:283-289, 1983.

14. Greenburg L, Mayers MR, Goldwater L, et al: Benzene (benzol) poisoning in the rotogravure printing industry In New Ywk City. *J Ind Hyg Toxicol* 21:295-420, 1939.

15. Aksoy M, Dincol K, Akgun T, et d: Hematological effects of chronic benzene poisoning In 217 workers. *Br J Ind Med* 28:296-302, 1971.

16. Townsend JC, On MC, Fishbeck WA: Health exam findings among individuals occupationally exposed to benzene. *J Occup Med* 20:543-548, 1978.

17. Fishbeck WA, Townsend JC, Swank MG: Effects of chronic occupational exposure to measured concentrations of benzene. *J Occup Med* 20:539-542, 1978.

18. Frederik WS: Am the present limits of normality in hematology acceptable for multiphasic health screening? *J Occup Med* 16:313-321, 1974.

19. Vecchio TI: The predictive value of a positive and a negative test. *N Engl J Med* 274:1171-1172, 1968.

20. US. Office of Technology Assessment: The Implications of Cost-effectiveness Analysis of Medical Technology: Background Paper No. 2. Case Studies of Medical Technologies. Case Study No. 4: Cost-effectivenss of Automated Multichannel Chemistry Analyzers, May, 1981.

Fleeting Beauty Captured

Throughout the English-speaking world the art of portraiture has been haunted for close to 350 years by the impossible perfection of Sir Anthony van Dyck, who was born in Antwerp in 1599 and died in London in 1641.

Van Dyck was an ornament to whatever society had the good sense to make him welcome. A great master of the public portrait, he had also a sense of human nature as something that needed all the order and the dignity that could legitimately be granted. How could he not have been welcome wherever he went?

When in Italy in his early 30s, he took it for granted that he would be accepted as a great gentleman. He looked the part, he dressed the put, he had a whde train of servants, he was in his own right an outstanding collector (he owned 19 Titians, for instance), and he felt entitled to negotiate with his sitters as prince with prince.

All this would have been ridiculous if the painting had been less good than they are. Van Dyck might have been one of the hundreds of portrait painters who tell white lies about their sitters and dress them up beyond their deserts. 8ut that he never did. He saw men and women alike with the eyes of an elegiac poet for whom beauty and riches and power were ephemeral attributes and all that mattered in the end was the beauty of the lived moment that would never recur.

— From "Art View: Van Dyck Remains the Quintessential Portrait Painter" by John Russell in *The New York Times*, December 19,1982