

OCCUPATIONAL HAZARDS IN PRODUCTION AND PROCESSING
OF STYRENE POLYMERS - EPIDEMIOLOGIC FINDINGS

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INTRODUCTION

Of the major plastic monomers, styrene is exceeded only by ethylene, propylene and vinyl chloride in terms of production. In 1977, approximately 3×10^6 metric tons were produced in the United States and 7×10^6 metric tons worldwide (IARC, 1979). Approximately 60% of the monomer produced was used in homopolymers, largely for the packaging industry. Other important uses of styrene are in the production of copolymers with acrylonitrile (SAN) and acrylonitrile and butadiene (ABS). Styrene also finds widespread use as a copolymer with butadiene in the production of the synthetic elastomer, styrene-butadiene rubber (SBR), which forms the basis of approximately 80% of U.S. rubber products. Finally, it is extensively used as a solvent and cross-linking agent for polyester resins in the fiber reinforced plastic (FRP) industry. Estimates of the number of workers employed in the various industries using styrene-based polymers are given in Table 1 along with typical exposure levels (Tossavainen, 1978). In addition to occupational exposure, low-level environmental contamination can occur from combustion of styrene-based products, as the thermal decomposition of polystyrene leads to evolution of the monomer, in contrast to other polymer materials.

MORTALITY STUDIES OF STYRENE-EXPOSED WORKERS

Studies on the mortality of populations exposed to styrene are fraught with difficulty because of confound-

Table 2
Population and follow-up characteristics of
three studies of styrene exposed workers

Study	Country	Analysis cohort size	Percent traced	Number of deaths analyzed	Percent of total
Ott et al. 1980	USA	2904	97.4	303	10.4
Nicholson et al. 1978	USA	560	100.0	83	14.8
Frentzel-Beyme et al. 1978	GER	1960	93.0Ger 29.0For	73	3.7
		Minimum exposure (years)	Minimum latency (years)	Years follow-up	Exposures
Ott et al. 1980		1	1	1940-1975	<10 ppm (3) ^a
Nicholson et al. 1978		5	10	1960-1975	<20 ppm (5)
Frentzel-Beyme et al. 1978		1 mo.	1 mo.	1956-1976	<1 ppmb

^a () = Estimated average exposure

^b Current measurement after installation of controls

The study of Nicholson et al (1978) successfully traced all of 563 men employed in styrene production, polymerization and polymer processing who had 5 years of employment on May 1, 1960 and were 10 years from onset of work in a large U.S. production facility. The basic mortality data are shown in Table 3 and demonstrate no excess mortality from any cause of death. Analyses according to years from onset of exposure and calendar years of observation did not reveal any pattern of excess mortality. However, because of the limited number of deaths, the data can be used only to establish upper limits of risk. For example, the data are only sufficient to indicate that the SMR for lymphoma or leukemia is less than 280 at the 0.05 level of significance and that of lung cancer, less than 220. While no excess mortality was identified in the cohort observed, the above publication mentioned the existence of 7 deaths from leukemia and 5 of malignancy of the lymphatic system among 444 deaths known to have occurred in the plant workforce. While the ages of death were not available for exact proportionate mortality calculations, the number of lymphomas is in line with expectations, while leukemia appears to be in excess by as much as a factor of two. However, the possibility of high exposures to benzene in the facility during earlier years weakens the likelihood

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Table 4

Observed and expected deaths by cause for total production
and non-professional research employees (2310 men), 1940-1976

Causes	Observed deaths	Expected deaths US white		Expected deaths, Company comparison	
		males	SMR		SMR
All causes	282	357.8	79	287.6	98
Malignant neoplasms	55	64.2	87	65.0	85
Respiratory system	14	20.8	67	23.9	59
Digestive system	16	18.0	89	21.2	67
Lymphatic and hematopoietic system except leukemia	6	4.5	133	2.6	230
Leukemia	6	2.9	207	1.6	375
Other sites	13	18.0	72	15.7	83
Cardiovascular disease	143	172.4	83	141.5	101
Nonmalignant respiratory dis.	12	14.3	84	10.0	120
All other causes	72	106.9	67	71.1	101

From Ott et al. 1980

concentrations of styrene (5-9 ppm). Because of a lack of a definitive exposure-response-relationship and the presence of possible confounding exposures, the authors refrained from drawing any conclusions on an etiological relationship.

In 1976, nine cases of various types of leukemia were identified in two SBR plants and reported to the U.S. National Institute for Occupational Safety and Health (Meinhardt et al, 1978). All occurred after 1971 in a population of 5,600 workers. No data were presented on the expected numbers of deaths from leukemia in the group. Concern generated by the findings in the two plants led to reports on the leukemias present in two large ongoing studies of rubber workers. McMichael et al (1976) reported a relative risk of 6.2 for lymphatic and hematopoietic malignancies among employees producing elastomers, including SBR. However, this was based upon only 6 cases, 3 leukemias and 3 lymphomas. In a subsequent case control study of the same plant, a relative risk of 2.4 was found for the same exposure group (Spiras et al, 1976). The difference in the two values reflect the uncertainties associated with small numbers of cases. A similar investigation by Monson et al (1978) showed an excess of leukemia to be present in calendering, extrusion, tire building and rubberized fabrics. However, the excess was associated with exposure to solvents and not to styrene.

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various respiratory symptoms, and gastrointestinal disturbances, such as nausea, vomiting and loss of appetite, are commonly reported by styrene-exposed workers. Other abnormalities reported include headaches, tiredness and sleep disturbance. After a period of exposure, adaptation may occur and there can be a decrease in the various symptoms. Nevertheless, significant alterations still exist among currently employed workers.

Several systematic studies of the various clinical effects from styrene exposure have been conducted in recent years. Many of these focused on possible neurological alterations and clearly demonstrated adverse findings at moderate styrene exposures (less than most national standards). The most extensive of these is that by investigators from the Institute of Occupational Health of Finland (Seppäläinen and Härkönen, 1976; Lindström et al, 1976; Härkönen, 1977; Härkönen et al, 1978). They examined 98 workers employed at 24 plants manufacturing FRP products. Air concentrations were sampled and ranged from 5 to 300 ppm. The means of five post-workday urine mandalic acid (MA) concentrations ranged from 7 to 4,700 mg/l with a linear relationship existing between the log of the MA concentration and the log of the styrene concentration. The mean value of MA in the population was 808 mg/l and corresponded to an exposure of about 40 ppm of styrene. Abnormal EEG's were found in 30% of those with MA in excess of 700 mg/l, compared to about 10% for those with lower MA values and normal controls (Seppäläinen and Härkönen, 1976). Lindström et al (1976) noted increased visuomotor inaccuracy (symmetry drawing and Bourdon-Wiersma tests) and lowered psychomotor performance (Mira test) for various MA concentrations ranging from 800-2,000 mg/l (See also: Härkönen et al, 1978). Fatigue, irritation, difficulty in concentration, nausea, dizziness, and lightheadedness were more frequently reported by the styrene-exposed workers than by unexposed controls (Härkönen, 1977).

A deteriorating EEG among styrene workers has also been described by Klimkova-Deutachova et al (1973). Alterations of nerve conduction have been documented by Rosén et al (1978) who observed an increased duration and decreased amplitude of sensory action potentials. Liliis et al (1978) suggested the possibility of a decrease in peroneal nerve conduction velocity. The decrease, however, was only associated with length of employment and not intensity of expo-

to other chemicals, such as benzene. The studies are severely limited because of the relatively low styrene exposure of the groups studied. They provide no guidance on carcinogenic risk in populations much more heavily exposed as in the FRP industry. The significant clinical findings among styrene-exposed workers are largely limited to abnormalities of the central nervous system, where a variety of objective and subjective symptoms have been reported in the FRP industry. Concern for long-term degenerative neurological disease exists for continued long-term exposure in this industry. The possibility of pulmonary effects from styrene exposure has also been noted.

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