

Morbidity among persons employed in styrene production, polymerization and processing plants

by A. M. THIESS and M. FRIEDHEIM¹

THIESS, A. M. and FRIEDHEIM, M. Morbidity among persons employed in styrene production, polymerization and processing plants. *Scand. j. work environ. & health* 4 (1978): suppl. 2, 203—214. BASF has been producing styrene and polystyrene since 1931. An investigation of morbidity was undertaken for 84 workers employed in the styrene plant and exposed for 1—36 years and 93 workers employed in the polystyrene plant and exposed for 1—38 years. In all groups the concentration of styrene in the atmosphere was measured at various points of the workplace. All workers underwent a thorough physical examination and also extensive laboratory tests, including the determination of urinary mandelic acid. The absenteeism and accident rates were also taken into consideration in both plants. Blood samples were also taken and mandelic acid tests made on a small group of 16 persons employed in polyester processing plants not attached to the BASF.

Key words: chemical industrial workers, morbidity, prospective study, styrene.

Styrene and polystyrene have been manufactured at the BASF Ludwigshafen works since 1931.

MANUFACTURE OF STYRENE AND CONCENTRATIONS OF STYRENE VAPOR IN THE AIR

Styrene is produced by the dehydrogenation of ethylbenzene over an iron oxide catalyst. The reaction mixture is fractionally distilled, yielding styrene, unreacted ethylbenzene, and its products of side reactions such as benzene and toluene (fig. 1).

For the assessment of the styrene concentrations to which employees might be exposed, periodic measurements were car-

ried out at the places in the plant indicated in fig. 1, and the presence of workers at these places was noted under the headings "constantly," "occasionally" (2—3 h/shift), or "patrols only" (visits lasting a few minutes two or three times a shift). Styrene concentrations were measured by gas chromatography, the limit of detection being about 0.01 ppm. Table 1 shows results obtained in 1975 and 1976. No concentration exceeded 10 ppm and most values were less than 1 ppm.

MANUFACTURE OF POLYSTYRENE AND CONCENTRATIONS OF STYRENE VAPOR IN AIR

Styrene polymers, including toughened styrene polymers, which contain rubber,

¹ Occupational Medicine and Health Protection, BASF Aktiengesellschaft, Ludwigshafen/Rhein, Federal Republic of Germany.

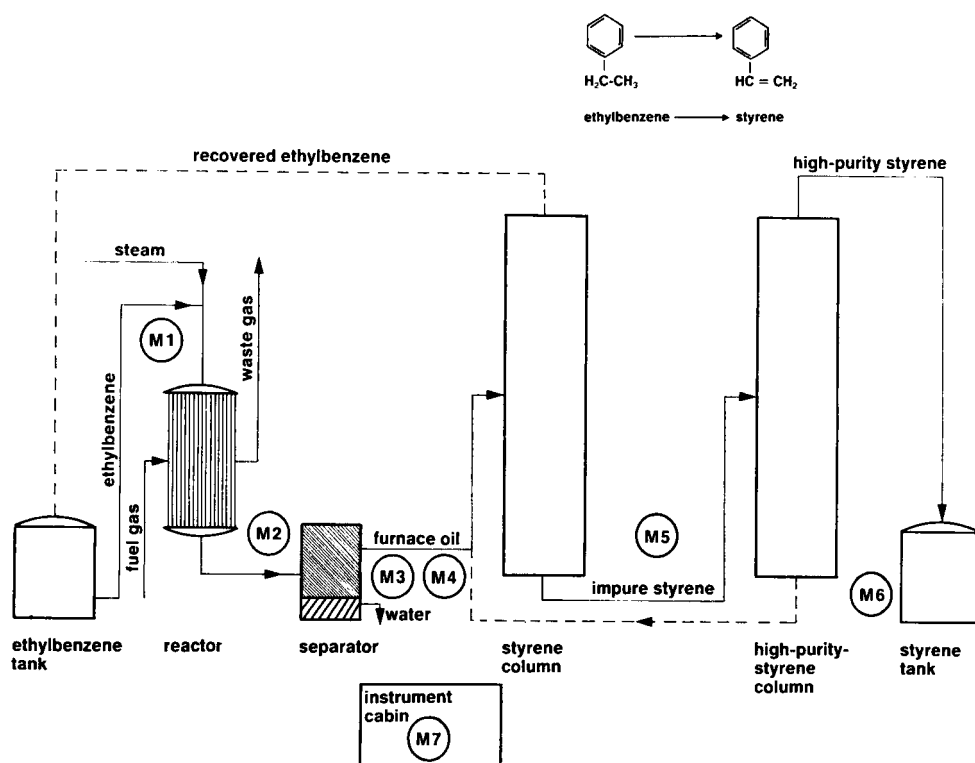


Fig. 1. Styrene site with air control points.

are made by polymerization in emulsion, suspension, or solution. Various auxiliary materials are added, depending on the process, and include peroxides, emulsifiers, suspension stabilizers, precipitants, solvents, and antioxidants.

Concentrations of styrene vapor in the air at various points of the plant and

ancillary buildings (fig. 2) were determined at intervals during 1975. The results are given in table 2. Generally, the concentrations were less than 1 ppm, but up to 8 ppm was found at places visited only by patrols, and on two occasions exceptionally high values for which there was no apparent reason were found.

Table 1. Volume concentrations^a of styrene vapor in the styrene plant, April 1975 to November 1976.

Position according to fig. 1	Persons present	Volume concentration (ppm)									
		1975					1976				
		26 April	3 June	7 July	25 Sept.		9 Jan.	29 April	19 June	8 Sept.	9 Nov.
1	Patrols only	0.01	0.08	0.01	0.17		0.00	0.19	0.14	0.00	0.00
2	Patrols only	1.56	0.12	0.01	0.02		0.48	0.08	0.46	0.00	1.32
3	Occasionally	6.84	0.08	0.02	0.24		0.14	0.02	2.40	0.00	0.10
4	Patrols only	0.02	0.02	—	0.06		0.08	0.43	0.58	0.00	0.02
5	Occasionally	0.08	0.06	3.72	0.14		0.02	0.02	—	0.00	0.84
6	Occasionally	0.24	0.12	0.20	2.52		0.72	0.36	3.24	0.08	0.37
7	Constantly	0.12	0.00	0.08	0.06		0.06	0.14	—	0.00	0.17

^a Limit of detection 0.01 ppm.

Table 2. Volume concentrations^a of styrene vapor in the polystyrene plant, February to October 1975.

Position according to fig. 2	Persons present	Volume concentration (ppm)							
		15 Feb.	22 March	26 April	24 May	5 Sept.	13 Oct.	14 Oct.	15 Oct.
1	Constantly	0.10	0.13	0.08	0.13	0.02	0.06	0.17	0.25
2	Occasionally	0.20	0.64	0.10	0.08	0.04	0.36	0.49	0.37
3	Constantly	0.28	0.23	0.14	0.06	0.14	0.53	0.44	0.24
4	Constantly	0.12	0.04	0.02	0.05	0.02	0.12	0.14	0.04
5	Constantly ^b	0.04	0.02	0.02	—	0.01	0.04	0.13	0.04
6	Constantly	0.08	0.07	0.32	0.18	0.06	0.08	0.20	0.16
7	Patrols only	0.91	0.85	7.34	5.60	1.68	8.28	46.92	21.27
8	Patrols only	1.93	4.75	1.56	1.18	1.84	3.04	8.89	4.42
9	Occasionally	0.05	0.11	0.02	0.12	0.49	—	0.20	0.05

^a Limit of detection 0.01 ppm.

^b Day shift only, weekdays.

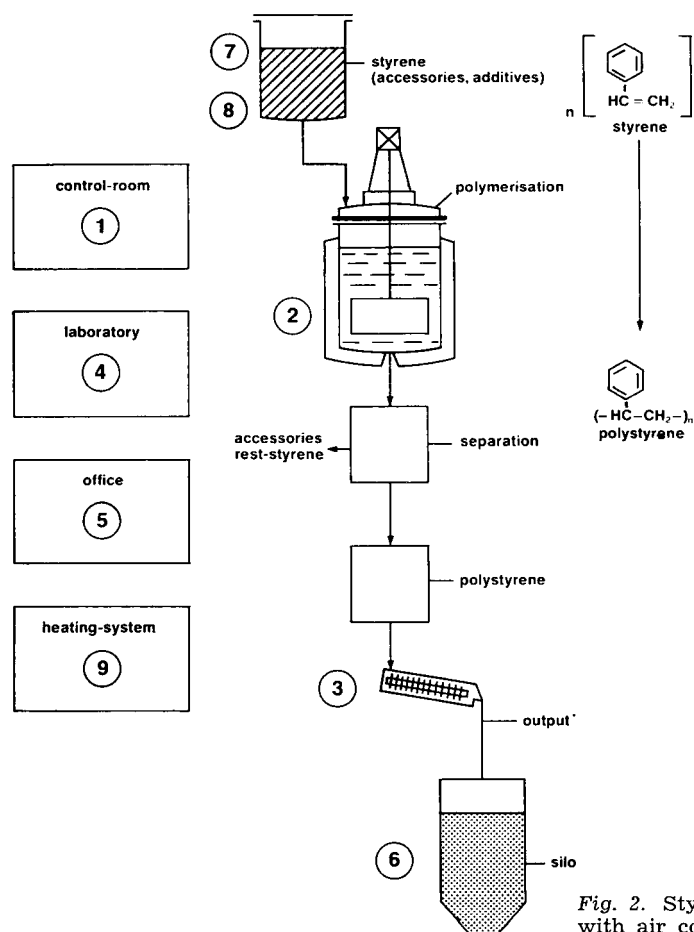


Fig. 2. Styrene polymerization, with air control points.

Table 3. Styrene air concentrations (plant A).

Location	Number of strokes	Styrene vapor in the air ^a (vol. fraction, ppm)
<i>Hand lay-up</i>		
1. Lamination with urethane foam	9	70
2. Molding aprons for rooflights	9	70
3. Molding aprons for rooflights	9	70
<i>Finishing</i>		
4. Impregnating roll, right	11	< 50
5. Squeeze roll, right	11	< 50
6. Impregnating roll, left	11	< 50
7. Squeeze roll, left	11	< 50
8. Spreader box, front right	11	< 50
9. Spreader box, rear left	11	< 50

^a Determined with Draeger tubes.

Table 4. Styrene air concentrations (plant B).

Location	Number of strokes	Styrene vapor in the air ^a (vol. fraction, ppm)
1. Roll mill, above	7	100
2. Roll mill, center	3	300
3. Equipment 6: above spreader box	4	200
4. Equipment 6, center: impregnating roll	5	160
5. Equipment 6: wind-up	8	80
6. Internal mixer after opening	5	160
7. Intermediate storage	13	50
8. Restroom	13	50
9. Rovings store	10	60

^a Determined with Draeger tubes.

POLYMERIZATION OF STYRENE OUTSIDE BASF

The manufacture and polymerization of styrene within BASF is carried out continuously in closed systems, but certain products containing free styrene, for instance, unsaturated polyesters, are converted manually by customers of BASF, who may use methods involving exposure

of their employees to comparatively high concentrations of styrene vapor. For this reason our investigations were extended in part to three plants where polymers containing free styrene are converted into finished or semi-finished articles. Concentrations of styrene in air at various points of these plants were determined, and a few of the workers were selected at random for determinations of mandelic acid in urine and a single blood analysis.

Plant A

Apart from end products of reinforced unsaturated polyester resins (moldings), plant A also manufactures corrugated sheets. The plant has about 400 employees. On the day when blood samples were taken the styrene concentrations (measured by means of Draeger tubes) were as shown in table 3. Records of measurements carried out in the past indicate higher concentrations, about 50–70 ppm, and explained the distinct rise in excretion of mandelic acid in the urine found in earlier tests. However, various modifications to the building and technical measures have in the meantime resulted in lower styrene concentrations at the place of work.

Plant B

Plant B has a total of 236 employees and produces polyester-impregnated mat and glass-reinforced epoxy or polyester moldings made by hand lay-up. Moldings are also made in presses from preimpregnated mat. Concentrations of styrene vapor, 50–300 ppm at various points in the plant, measured with Draeger tubes, are given in table 4.

Plant C

Plant C employed 48 persons in the manufacture of plastic articles, primarily containers and boats made from glass-reinforced epoxy resins with the hand lay-up method. This method involves spreading mixtures of epoxy resins and styrene on glass fiber mat. The styrene concentrations (50–300 ppm) at various points in the plant, measured by means of Draeger tubes, are given in table 5.

RESULTS

In all, 177 BASF employees working at the Ludwigshafen works were examined; 84 of these were engaged in styrene manufacturing and 93 in polystyrene manufacturing. Each person was asked about his work history, and the period of potential exposure to styrene was determined.

After the clinical histories had been taken, each person was subjected to a thorough physical examination that included measurement of height, weight, blood pressure, pulse rate, and vital capacity and a radiological examination of the thoracic organs.

The laboratory tests included blood counts (with differential blood counts), thrombocyte counts, determination of serum glutamate-oxalacetate transaminase (SGOT), serum glutamate-pyruvate transaminase (SGPT), gamma-glutamyl transferase (gamma-GT), lactate dehydrogenase (LDH), alkaline phosphatase, total bilirubin, total albumen, and blood sedimentation, the thymol test, determination of urine status, and determinations of urea and creatinine.

Employees engaged in styrene manufacture

The ages of the 84 employees investigated ranged from 19 to 59 years. The exposure times varied from 1 to 36 years.

Table 6 gives a summary of the diseases recorded in the case histories.

Eight persons (10 %) had high blood pressure (in excess of 160/95 mm Hg). There were no cases of systolic blood pressure less than 100 mm Hg.

The radiographs of the thorax disclosed no considerable changes since the subjects were examined before taking up work with the company. Neither were there gross pathological indications in the electrocardiograms.

To assist interpretation of the laboratory results, comparisons were made with a reference group consisting of 62 BASF employees with comparable working and living conditions who worked in another production plant. The age distributions of the two groups are shown in table 7. The number of referents was somewhat

Table 5. Styrene air concentration (plant C).

Location	Number of strokes	Styrene vapor in the air ^a (vol. fraction, ppm)
1. Workshop	9—10	60
2. Lay-up station, near extraction fan	7	100
3. Impregnation, at nose height	4	200
4. In mold building	11	50
5. Mold building, lamination room, at nose height	4—5	180
6. Molding press, loaded with resin	8	85
7. Coating, application of adhesive	5	160
8. Lamination, air extraction	3	300
9. Lamination, air extraction	4	200
10. Lamination, 5 m away	6	130
11. One-off lamination with mat	5	160

^a Determined with Draeger tubes.

Table 6. Clinical history of the styrene plant.

Type of disease	Number of cases
Gastrointestinal diseases	19
Hepatic diseases	11
Chronic nephrolithiasis	5
Diabetes mellitus	2
Hypertension — hypotension	7
Chronic bronchitis	6
Pulmonary tuberculosis	2
Typhoid	1
Malaria	1
Other illnesses	2

Table 7. Age distribution of persons examined in the monostyrene and reference groups.

Age (years)	Number	
	Reference	Monostyrene
15—25	4	7
25—35	17	12
35—45	19	34
45—55	14	19
55—65	8	12
total	62	84

Table 8. Abnormal laboratory findings — styrene.

Laboratory examinations		Reference group	Reference group		Styrene group	
		Exact figure	Exact figure	Percentage	Exact figure	Percentage
Hemoglobin (g %)	< 13.6	62	4	6.9	2	2.4
Erythrocytes (mm ⁻³)	< 4.5×10^4	62	15	23.9	0	0
Leucocytes (mm ⁻³)	> 9,000	61	20	33.5	15	17.9
Serum glutamate-oxalacetate transaminase (u/ml)	> 17	61	7	11.5	5	6.0
Serum glutamate-pyruvate transaminase (u/ml)	> 23	61	14	23.0	9	10.7
Gamma-glutamyl transferase (u/ml)	> 28	60	8	13.3	23	27.5

Table 9. Supplementary laboratory findings in the styrene group.

Laboratory examinations		Abnormal values	
		Exact figure	Percentage
Thrombocytes (mm ⁻³)	130,000—350,000	0	0
Thymol (ML units)	0—3.0	3	3.6
Lactate dehydrogenase (u/ml)	80—240	2	2.4
Alkaline phosphatases (u/ml)	50—190	2	2.4
Total bilirubin (mg %)	0.2—1.0	2	2.4
Total proteins (mg %)	6.7—8.7	2	2.4
Urea (mg %)	20—50	3	3.6
Creatinine (mg %)	0.8—1.2	2	2.4

Table 10. Increased serum glutamate-oxalacetate transaminase findings — styrene.

Age (years)	Values exceeding 17 u/ml			
	Reference group		Styrene group	
	Exact figure	Percentage	Exact figure	Percentage
15—25	0	0	0	0
25—35	2	11.8	1	8.3
35—45	4	21.1	1	2.9
45—55	1	7.1	2	10.5
55—65	0	0	1	8.3

Table 11. Increased serum glutamate-pyruvate transaminase findings — styrene.

Age (years)	Values exceeding 17 u/ml			
	Reference group		Styrene group	
	Exact figure	Percentage	Exact figure	Percentage
15—25	0	0	1	14.3
25—35	6	35.3	1	8.3
35—45	6	31.6	5	14.7
45—55	1	7.1	2	10.5
55—65	1	12.5	0	0

less than the number exposed to styrene monomer.

Table 8 gives a comparison of the numbers and proportions of those subjects whose clinical laboratory results can be

regarded as abnormal. Within the styrene group the proportions with abnormally low hemoglobin or erythrocyte values or abnormally high leucocyte, SGOT or SGPT values were less than in the ref-

erence group. The proportion in the styrene group having abnormally high gamma-GT values was greater than the proportion in the reference group, but not significantly so at the 0.05 level as determined by the Fisher and Yates tests (4). In fact, the only difference found to be statistically significant was between the proportions with abnormally low erythrocyte values.

The results of the additional tests carried out only on the styrene group are given in table 9.

Tables 10, 11 and 12 give the incidences of abnormal values for SGOT, SGPT, and gamma-GT for the styrene and reference groups, broken down according to age. Because of the low numbers in each category the results must be interpreted with great reserve. There were in fact no differences that could be regarded as statistically significant according to the exact test of Fisher and Yates (4). It should be added that the three parameters chosen are those that might have given indication of possible damage to the liver through exposure to styrene.

The incidences of abnormal SGOT, SGPT, and gamma-GT values in the styrene group are shown broken down by exposure time in table 13. The table indicates no trend towards a higher incidence with longer exposure, even in the case of the gamma-GT values, which were somewhat higher than in the reference group.

Table 12. Increased gamma-glutamyl transferase findings — styrene.

Age (years)	Values exceeding 28 u/ml			
	Reference group		Styrene group	
	Exact figure	Per- centage	Exact figure	Per- centage
15—25	0	0	2	28.6
25—35	1	6.3	4	33.3
35—45	3	16.7	10	29.4
45—55	1	7.1	6	31.6
55—65	3	37.5	1	8.3

Employees engaged in the manufacture of styrene polymers

The age distribution of the 93 employees engaged in the manufacture of styrene polymers varied from 19 to 64 years, but most of the employees were aged between 35 and 55 years. The distribution of exposure times varied from 1 to 38 years.

Diseases suffered by employees before they joined BASF, as given in the case histories, are summarized in table 14. High blood pressure (more than 160/95 mm Hg) was found in 11 employees, and 1 employee had a systolic blood pressure of less than 100 mm Hg. Again the radiographs of the thorax varied little from those taken before the employee joined the company.

The results of the more important clinical laboratory tests were compared with

Table 13. Abnormal results of liver function tests after exposure to styrene in the styrene production plant.

Exposure (years)	Serum gluta- mate-oxalace- tate transami- nase > 17 mU (%)	Serum gluta- mate-pyruv- ate transami- nase > 23 mU (%)	Gamma-gluta- methyl trans- ferase > 28 mU (%)
0—5 (N = 20)	5	10	30
5—10 (N = 9)	0	11.1	22.2
10—18 (N = 18)	8.7	8.7	26
>18 (N = 32)	6.3	12.5	28.1

Table 14. Clinical history of the polystyrene plant.

Type of disease	Number of cases
Gastrointestinal diseases	22
Hepatic diseases — gall bladder diseases	
Upper abdominal complaints	
of undefined etiology	11
Nephrolithiasis	4
Diabetes mellitus	5
Hypertension — hypotension	8
Chronic bronchitis	
Bronchial asthma	8
Malaria	4
Other illnesses	4

Table 15. Age distribution of the polystyrene and reference groups.

Age (years)	Number	
	Reference group	Polystyrene group
15—25	4	4
25—35	17	13
35—45	19	38
45—55	14	25
55—65	8	13
Total	62	93

Table 16. Abnormal laboratory findings — polystyrene.

Laboratory examinations		Reference group	Reference group		Polystyrene group	
		Exact figure	Exact figure	Percentage	Exact figure	Percentage
Hemoglobin (g %)	< 13.6	62	4	6.9	4	4.3
Erythrocytes (mm ⁻³)	< 4.5×10^4	62	15	23.9	11	11.8
Leucocytes (mm ⁻³)	> 9,000	61	20	33.5	32	34.4
Serum glutamate-oxalacetate transaminase (u/ml)	> 17	61	7	11.5	9	9.7
Serum glutamate-pyruvate transaminase (u/ml)	> 23	61	14	23.0	21	22.6
Gamma-glutamyl transferase (u/ml)	> 28	60	8	13.3	20	21.5

Table 17. Supplementary laboratory findings in the polystyrene group.

Laboratory examinations		Abnormal values	
		Exact figure	Percentage
Thrombocytes (mm ⁻³)	130,000—350,000	1	1.1
Thymol (ML units)	0—3.0	5	5.4
Leucinamino-peptidase (u/ml)	11—35	1	1.1
Lactate dehydrogenase (u/ml)	80—240	2	2.2
Alkaline phosphatases (u/ml)	50—190	1	1.1
Total bilirubin (mg %)	0.2—1.0	1	1.1
Total proteins (mg %)	6.7—8.7	0	0
Urea (mg %)	20—50	1	1.1
Creatinine (mg %)	0.8—1.2	1	1.1

Table 18. Increased serum glutamate-oxalacetate transaminase findings — polystyrene.

Age (years)	Values exceeding 17 u/ml			
	Reference group		Polystyrene group	
	Exact figure	Percentage	Exact figure	Percentage
15—25	0	0	0	0
25—35	2	11.8	1	7.7
35—45	4	21.1	3	7.9
45—55	1	7.1	5	20.0
55—65	0	0	0	0

Table 19. Increased serum glutamate-pyruvate transaminase findings — polystyrene.

Age (years)	Values exceeding 23 u/ml			
	Reference group		Polystyrene group	
	Exact figure	Percentage	Exact figure	Percentage
15—25	0	0	0	0
25—35	6	35.3	2	15.4
35—45	6	31.6	10	26.3
45—55	1	7.1	8	32.0
55—65	1	12.5	1	7.7

those for the reference group with which the styrene group was compared. The age distributions of both groups are given in table 15; the reference group was somewhat smaller than the polystyrene group. Table 16 gives the incidence of abnormal values for both groups. Only the incidences of abnormally low erythrocyte counts were found to be statistically significant at the 0.05 level by the Fisher and Yates test (4), and again the lower incidence was in the polystyrene group.

The results of the other tests to which the members of the polystyrene group were subjected are summarized in table 17.

The incidences of abnormal SGOT, SGPT, and gamma-GT values, broken down by age groups, are compared in tables 18, 19 and 20. None of the differences was found to be statistically significant by the exact test of Fisher and Yates, although, as before, the small numbers in each category demand that

the figures be interpreted with a certain amount of reserve.

The breakdown by exposure time of incidences of abnormal SGOT, SGPT, and gamma-GT values is given in table 21; there is no evidence of a trend towards higher incidences with longer exposure.

Table 20. Increased gamma-glutamyl transferase findings — polystyrene.

Age (years)	Values exceeding 28 u/ml			
	Reference group		Polystyrene group	
	Exact figure	Percentage	Exact figure	Percentage
15—25	0	0	0	0
25—35	1	6.3	3	23.1
35—45	3	16.7	9	23.7
45—55	1	7.1	7	28.0
55—65	3	37.5	1	7.7

Table 21. Abnormal results of liver function tests after exposure to styrene in the polystyrene production plant.

Exposure time (years)	Serum glutamate-oxalacetate transaminase > 17 mU (%)	Serum glutamate-pyruvate transaminase > 23 mU (%)	Gamma-glutamyl transferase > 28 mU (%)
0—5 (N = 18)	11.1	22.2	22.2
5—10 (N = 17)	5.9	23.5	17.6
10—18 (N = 42)	14.3	26.2	23.8
>18 (N = 18)	0	12.5	18.8

Wage earners exposed to styrene in plants outside BASF

A small proportion — 16 workers in all — of the employees of the three non-BASF plants voluntarily submitted to tests. The ages and exposure times are given in table 22, the former being between 36 and 51 years and the latter between 2 and 24 years.

Table 23 gives the incidences of abnormal clinical laboratory values for each of the three plants. The numbers of people involved were too low to allow definite conclusions to be drawn from the results.

The main purpose of taking blood samples from these workers was to allow comparison of chromosome analyses with

analyses of BASF employees exposed to styrene in the manufacture of styrene and styrene polymers.

MANDELIC ACID IN URINE

The principle metabolite of styrene is 2-hydroxy-2-phenylacetic acid (mandelic acid), which is excreted in the urine. In occupational medicine a mass concentration of 350 mg/l in the urine is regarded as just tolerable. Determinations of mandelic acid in urine were carried out for us by the Institute for Occupational and Social Medicine at the University of Erlangen (6). The mandelic acid was determined by gas chromatography, the limit of detection being about 10 mg/l.

Fig. 3 shows the distribution of the mandelic acid concentrations in the urine of 67 employees engaged in the manufacture of styrene or polystyrene at the BASF Ludwigshafen works and 16 employees of the three non-BASF plants. The urine of all except six of the 67 BASF employees contained less than 50 mg of mandelic acid per liter. Of the 16 employees of the three non-BASF plants, only five had mandelic acid concentrations less than the limit of

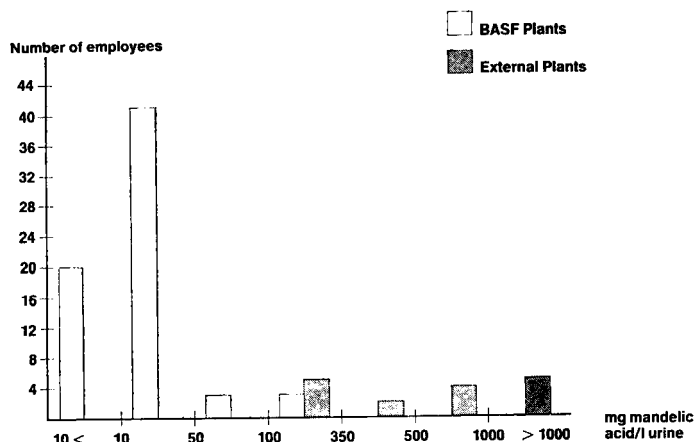
Table 22. Number, age and period of exposure for employees in the external styrene-processing plants.

Plant	Number of employees	Age (years)	Exposure (years)
A	4	37—46	5—9
B	6	36—51	2—24
C	6	37—46	2—14

Table 23. Laboratory results (external styrene-processing plants).

Laboratory examinations		Abnormal results		
		Plant A	Plant B	Plant C
Hemaglobin	< 13.6	0	0	0
Erythrocytes	< 4.5×10^4	0	0	0
Leucocytes	> 10,800	0	0	0
Serum glutamate-oxalacetate transaminase (u/ml)	> 17	1	0	1
Serum glutamate-pyruvate transaminase (u/ml)	> 23	1	2	1
Gamma-glutamyl transferase (u/ml)	> 28	1	4	0
Thrombocytes	130,000—350,000	0	0	0
Lactate dehydrogenase (u/ml)	80—240	0	0	0
Alkaline phosphatases	50—190	0	0	0
Total bilirubin (mg ‰)	0.2—1.0	0	1	1
Total albumen (mg ‰)	6.7—8.7	0	0	0
Urea (mg ‰)	20—50	0	1	2
Creatinine (mg ‰)	0.8—1.5	0	0	1

Fig. 3. Mandelic acid in the urine of employees exposed to monostyrene in the styrene, polystyrene and external styrene processing plants.



350 mg/l, and, of these five, three were from plant A, where volume concentrations of styrene vapor were found to be less than 100 ppm. Of the remaining 11 people with mandelic acid concentrations exceeding 350 mg/l only one was from plant A, the rest being from plants B and C, where volume concentrations of styrene vapor of up to 300 ppm had been measured.

DISCUSSION

The objective of the investigation was to establish whether or not the health of employees engaged in the manufacture of styrene or styrene polymers (7) was appreciably different from that of other workers. Since it was stated in Russian literature (4, 5, 8, 9) that workers had disturbances of the functions of the liver and gall bladder, we paid particular attention to this matter. We sought especially to establish whether or not disturbances to health were detectable when employees were exposed to low concentrations of styrene vapor for long periods.

In the BASF plants the concentrations of styrene vapor in the air of places occupied by employees were well below the maximum allowable concentration in the Federal Republic of Germany (100 ppm).

The concentrations of mandelic acid in the urine of the employees concerned were

correspondingly low. In three non-BASF plants in which the styrene concentrations were much greater than in the BASF plants, the concentrations of mandelic acid in the urine of employees were considerably higher.

Since the employees of the three non-BASF plants were not under our medical supervision, it was not possible to form an impression of their general state of health. Although we examined a blood sample from four or six employees from each of the plants concerned, this was done mainly to discover possible chromosome aberrations resulting from exposure to the high concentrations of styrene known to prevail in parts of these plants. The results of the chromosome analyses have been reported separately by Fleig and Thiess (1).

The 84 employees engaged in styrene manufacture and the 93 employees engaged in the manufacture of styrene polymers were compared with a reference group of 62 other employees engaged in production at the Ludwigshafen works of the BASF. The incidences of abnormal values for hemoglobin, erythrocytes, leucocytes, SGOT, SGPT, and gamma-GT were compared. Compared with the reference group, the incidence of abnormal gamma-GT values was slightly, but not significantly, higher in the styrene and polystyrene groups. The incidences of abnormal values for the other parameters showed no differences unfavorable to the styrene and polystyrene groups.

In the event of long exposure to styrene vapor causing damage to health, the period

of exposure would be important. The figures in tables 13 and 21 however show no evidence of an increase in pathological liver function values with increasing exposure time, either in the styrene or in the polystyrene groups.

The investigation into the rate of sickness and accidents in the styrene and polystyrene plant showed no significant difference compared with the works as a whole.

A study of mortality among employees engaged in the manufacture of styrene or styrene polymers at the Ludwigshafen works has been reported separately by Frentzel-Beyme and Thiess (2).

ACKNOWLEDGMENTS

We wish to express our thanks to Prof. Valentin, Director of the Institute for Occupational and Social Medicine at the University of Erlangen, and Dr. Schaller for their kind assistance in carrying out the determinations of mandelic acid in urine.

In addition we should also like to thank Ms. H. Kubis, Mr. H. Hochadel and Mr. G. Kattermann.

REFERENCES

1. FLEIG, I. and THIESS, A. M. Mutagenicity study on workers employed in the styrene and polystyrene processing and manufacturing industry. *Scand. j. work environ. & health* 4 (1978): suppl. 2, 254—258.
2. FRENTZEL-BEYME, R., THIESS, A. M. and WIELAND, R. Survey of mortality among workers engaged in the manufacture of styrene and polystyrene at the BASF Ludwigshafen works. *Scand. j. work environ. & health* 4 (1978): suppl. 2, 231—239.
3. KAC, B. J. Chemotoxic liver damage by styrene under industrial working conditions (in Russian). *Gig. tr. prof. zabol.* 6 (1962) 21—24.
4. LIENERT, G. A. *Verteilungsfreie Methoden in der Biostatistik* (vol. I). Anton Hain-Verlag 1973, p. 171.
5. OLTRAMARE, M., DESBAUMES, E., IMHOFF, C. and MICHIELS, W. *Toxicologie du styrene monomère*. Editions Médecine et Hygiène, Genève 1974.
6. SCHALLER, K. H., GOSSLER, K., BOST, H. P. and VALENTIN, H. Gaschromatographische Methoden zur Bestimmung von Styrol in Blut sowie von Mandelsäure und Phenylglyoxylsäure in Urin. *Arbeitsmed. Sozialmed. Präventivmed.* 1 (1976) 24—26.
7. THIESS, A. M., FRIEDHEIM, M. and ROSSMANN, H. Occupational medical investigations on workers employed in styrene polymerization. *Polym. prepr.* 17 (1976): 1, 35—37.
8. TROSINA, I. M. Characteristics of morbidity among employees working with styrene (in Russian). *Gig. tr. prof. zabol.* 7 (1963) 17—21.
9. ZLOBINA, N. S. On the toxicity of low concentrations of styrene vapour (in Russian). *Gig. sanit.* 28 (1963) 29—35.