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Polycyclic aromatic hydrocarbons in the work atmosphere

Determination of area-specific concentrations and job-specific exposure in a vertical pin Söderberg aluminum plant

by Alf Bjørseth, PhD,¹ Olav Bjørseth, MSc,² Per E Fjeldstad, MSc³

BJØRSETH A, BJØRSETH O, FJELDSTAD PE. Polycyclic aromatic hydrocarbons in the work atmosphere: Determination of area-specific concentrations and job-specific exposure in a vertical pin Söderberg aluminum plant. *Scand j work environ health* 7 (1981) 223—232. Polycyclic aromatic hydrocarbons (PAH) and particulates in the work atmospheres of the potrooms and anode paste plant of an aluminum reduction plant were determined by stationary and personal sampling and a glass capillary gas chromatographic method. The relative distribution of PAH (PAH profile), the fraction of PAH on particulates, and the ratio between particulate and gaseous PAH were also determined. The PAH profile was found to be similar to that found for another aluminum plant. The PAH fraction of particulate matter was generally between 1 and 4 %, and the ratio between particulate and gaseous PAH in the potrooms varied from 0.2 to 1. The occupational exposures were determined from an analysis of a total of 167 personal samples. For most job categories, the geometric mean of the exposure values was higher than 40 $\mu\text{g}/\text{m}^3$, spike pulling having the highest exposure of the categories measured.

Key terms: aluminum reduction plant, sampling, analysis, occupational exposure, benzo(a)pyrene, coal tar pitch volatiles, glass capillary gas chromatography.

Aluminum production involves heating carbonaceous electrode materials to temperatures around 1,000 °C, under which coal tar pitch volatiles (CTPV) and particularly polycyclic aromatic hydrocarbons (PAH) may be released. Consequently, aluminum reduction workers may be exposed to CTPV or PAH in such areas as the potroom and carbon plant and during operations such as rodding, pot repair, pot tending, anode work, and paste production (15). This exposure poses a potential health

hazard (14), and epidemiologic studies on the subject have recently been published for aluminum reduction workers (11, 13), as well as for other occupations (10, 12).

Many PAH have been shown to exhibit carcinogenic properties (8, 9), and there is a considerable interest in characterizing these compounds in work atmospheres. PAH have been detected in soot from an aluminum plant (16) and in stationary and personal samples (4). Analyses of particulates from the work atmosphere in an aluminum plant by computerized gas chromatography-mass spectrometry also revealed that more than 100 PAH compounds could be identified or detected (6).

Despite these investigations, little is known about the relationship between area-specific PAH concentrations and job-related exposure to PAH. As part of a research program on the occurrence and analysis of PAH in work atmospheres, we have previously reported an analytical

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method for determining PAH (2) and PAH concentrations in a Söderberg paste plant, an aluminum plant, and a coke plant (4, 5, 7). In the present paper we present the results of an investigation of PAH in air and airborne particulates in a relatively new aluminum plant with vertical pin Söderberg electrodes. Both stationary (area specific) and personal (job specific) samplings were utilized, and the occupational

exposure was determined. Furthermore, the day-to-day variation in the exposure of one worker, as well as the variations within the same job type, have been studied. The relative distribution of PAH compounds (PAH profile) has been compared to those previously published. The ratio between gaseous and particulate PAH has also been determined for the stationary samples.

Fig 1. Glass capillary gas chromatograms of polycyclic aromatic hydrocarbons in the gaseous state (upper half of figure) and on particulates (lower half of figure) in a potroom atmosphere. For peak identity see table 2.

Materials and methods

Plant description

The investigated aluminum smelter is the newest in Norway; it came on stream in 1971. The smelter has three potrooms, each containing 88 computer-operated Söderberg pots with vertical spikes. The potrooms are connected with open hallways. Potroom 3 is the newest and best ventilated of the three. It is equipped with a clean-air conditioned spikepuller cabin. The annual production of aluminum is approximately 80,000 t. Anode paste is

supplied from an adjacent paste plant. The plant also has a separate pot repair and relining shop.

Sampling method

The personal samples were collected with a personal sampler (Casella) in connection with a membrane filter (Acropore AN 800) 37 mm in diameter placed in the breathing zone of the workers (outside the mask if in use). The flow rate was about 2 l/min.

In order to get larger amounts of particulate and also volatile matter, we used a stationary sampling device. This device

Table 1. Results from stationary sampling, three potrooms and the anode paste plant. (PAH = polycyclic aromatic hydrocarbons)

Sampling site	Dust (mg/m ³)	Particulate PAH (mg/m ³)	Gaseous PAH (mg/m ³)	Total PAH (mg/m ³)	PAH fraction on dust (%)	Particulate PAH/gaseous PAH
Potroom 1	0.60	0.014	0.081	0.095	2.3	0.173
	1.71	0.050	0.037	0.087	2.9	1.351
	1.35	0.034	0.090	0.124	2.5	0.378
	1.44	0.034	0.128	0.162	2.4	0.265
	1.06	0.031	0.078	0.109	2.9	0.397
	1.31	0.035	0.062	0.097	2.7	0.565
Potroom 2	0.99	0.017	0.139	0.156	1.7	0.122
	1.75	0.019	0.057	0.076	1.1	0.333
	1.59	0.028	0.060	0.088	1.8	0.467
	2.31	0.033	0.041	0.074	1.4	0.805
	1.09	0.019	0.075	0.093	1.7	0.253
	1.61	0.016	0.066	0.082	1.0	0.242
	0.884	0.016	0.061	0.077	1.8	0.262
	6.52	0.034	0.056	0.090	0.52	0.607
	1.45	0.023	0.030	0.053	1.6	0.767
	1.39	0.030	0.039	0.069	2.2	0.769
	1.29	0.016	0.018	0.034	1.2	0.889
	1.67	0.051	0.049	0.100	3.1	1.041
	2.27	0.045	—	0.045	2.0	—
Potroom 3	0.523	0.020	0.044	0.064	3.8	0.455
	1.612	0.032	0.067	0.099	2.0	0.478
	0.346	0.016	0.015	0.031	4.6	1.067
	1.556	0.063	0.065	0.128	4.1	0.969
	1.415	0.017	0.074	0.091	1.2	0.230
	0.686	0.093	—	0.093	13.6	—
	1.917	0.081	0.089	0.170	4.2	0.910
	0.838	0.058	0.032	0.090	6.9	1.812
	1.523	0.092	0.130	0.222	6.0	0.708
	1.121	0.067	0.088	0.155	6.0	0.761
	1.390	0.072	0.073	0.145	5.2	0.986
	0.635	0.040	0.073	0.113	6.3	0.548
	1.059	0.021	—	0.021	2.0	—
	1.096	0.059	0.103	0.162	5.4	0.573
Anode paste plant	10.28	3.906	2.977	6.882	38.0	1.312
	4.11	1.559	1.988	3.548	37.9	0.784

consisted basically of a membrane filter (Acropore AN 800, 47-mm Ø) and two absorption bottles in series, each filled with ethanol. The bottles were cooled with dry ice to reduce the evaporation of ethanol. A vacuum pump (Edwards ECBI) drew the air through the system with a flow rate of approximately 1 m³/h. The sampling volume was measured with a dry gas meter.

Sample collection — personal samples

Several workers with the same job type carried personal sampling pumps during five consecutive shifts per day. The sampling duration was around 6 h, and the typical sampling volume was 0.6 m³. A total of 167 personal samples was collected from 18 different job types during the 7-d sampling period in February 1977.

Table 2. Typical distribution of particulate and gaseous polycyclic aromatic hydrocarbons (PAH) in stationary samples from an aluminum plant.

Peak number ^a	Compound	Particulate PAH (µg/m ³)	Gaseous PAH (µg/m ³)	Total PAH (µg/m ³)
1	Naphthalene		15.09	15.09
2	2 — Methyl-naphthalene		8.94	8.94
3	1 — Methyl-naphthalene		5.10	5.10
4	Biphenyl		1.51	1.51
	Acenaphthylene		14.74	14.74
6	Acenaphthene		4.11	4.11
7	Dibenzofuran		< 0.03	< 0.03
8	Fluorene		9.24	9.24
	9 — Methylfluorene		2.65	2.65
10	2 — Methylfluorene		0.48	0.48
11	1 — Methylfluorene		1.30	1.30
12	Dibenzothiophene		2.09	2.09
13	Phenanthrene	1.49	43.50	44.98
14	Anthracene	0.10	3.90	4.00
15	Carbazole	0.96	—	0.96
16	2 — Methylanthracene	0.37	0.20	0.58
17	1 — Methylphenanthrene	0.10	0.60	0.70
18	9 — Methylanthracene	0.11	< 0.03	0.11
19	Fluoranthene	7.58	6.71	14.29
20	Dihydrobenzo(a,b)fluorene	0.21	0.20	0.41
21	Pyrene	5.36	3.29	8.65
22	Benzo(a)fluorene	1.50		8.65
23	Benzo(b)fluorene			
24	4 — Methylpyrene	0.39		0.39
25	1 — Methylpyrene	0.47		0.47
26	Benzo(c)phenanthrene	0.31		0.31
27	Benz(a)anthracene	2.28		2.28
28	Chrysene/Triphenylene	4.43		4.43
29	Benzo(b)fluoranthene			
30	Benzo(j,k)fluoranthenes	4.64		4.64
31	Benzo(e)pyrene	1.45		1.45
32	Benzo(a)pyrene	0.85		0.85
33	Perylene	0.26		0.26
34	Indeno(1, 2, 3-cd)pyrene	0.61		0.61
35	Benzo(ghi)perylene	0.63		0.63
	Anthanthrene	< 0.02		< 0.02
	1,2—3,4 Dibenzpyrene	"		"
	Coronene	"		"
Total		34.1	123.7	164.9

^a Referring to fig 1.

Sample collection — stationary samples

Stationary samples were collected in the potroom about 1.5 m above the floor. Six stationary units were used simultaneously, and 32 samples were taken during the sampling period. The typical sampling volume was 3 m³.

In the anode paste plant, the stationary sampling site was located above the briquetting machine. Two samples were taken during the sampling period.

Analytical procedure

The analytical method for stationary samples was based on a Soxhlet extraction of the particulates, a liquid-liquid extraction clean-up, and a glass capillary gas chromatographic separation. Descriptions of the procedure, precision, and accuracy have been given elsewhere (2).

The personal samples were extracted twice with ethanol in an ultrasonic bath using 4-ml portions of solvent and sonicating for 20 min each time. The quantification of PAH was performed on a high-pressure liquid chromatograph (HPLC) using a silica gel column (Nucleosil 100-5, Macherey-Nagel & Co) and isooctane as the mobile phase. The procedure and comparison with gas chromatography have been given elsewhere (3).

Stationary sampling

Stationary samples were collected in three potrooms and the anode paste plant. Fig 1 shows typical gas chromatograms of PAH in the gaseous state and on particles. A total of 38 compounds was identified, some of which were found both on the particles and in the vapor phase.

The concentrations of dust, total particulate, and gaseous PAH in the potrooms and the anode paste plant are given in table 1. The PAH fraction of particulate matter and the ratio between gaseous and particulate PAH is also given for each sample. Table 2 gives typical values for the distribution between particulate and gaseous PAH identified in the stationary samples. As revealed by the tables, the

concentration varied considerably within each potroom and between the different potrooms and the paste plant.

Fig 2 shows the PAH profiles (4) for total PAH in the three potrooms. The general trend was similar for all three potrooms; however, potroom 3 seemed to have somewhat lower concentrations of the high molecular PAH and a corresponding increase in the more volatile compounds such as fluoranthene and pyrene. This phenomenon was probably due to the fact that the spikepuller machine in potroom 3 required a softer paste than ordinary Söderberg anodes and hence released more volatile compounds. The profiles were also similar to that observed in a study of a different aluminum plant (4).

Personal sampling

The concentrations of total PAH (defined as sum of all PAH identified or detected by gas chromatography) for different workers over a sequence of several days are shown in table 3. These samples only give a measure of particulate PAH.

Fig 2. Polycyclic aromatic hydrocarbon profiles for the three potrooms of the aluminum plant.

Table 3. Total particulate polycyclic aromatic hydrocarbon exposure over several consecutive days
— Personal sampling.

Job category	Exposure ($\mu\text{g PAH}/\text{m}^3$)				
	Day 1	Day 2	Day 3	Day 4	Day 5
Paste plant operations	405 314 196	94 1,076 1,185	71 7.8 5.0	7.7 64 49	
Pot lining, tamping			82		150 371 143 180
Gas cleaning, day work	39 48	12 11	67 80 854	234	
Dust cleaning		32 87	94 82	29 45	147 64
Tapping	13 11 50	32 20 19	17	34	
Pot operating, day work		94 51 54	55 54 28	30 32 37	43 47 62
Foreman				(1,659)	8
Anode paste charging	17	17	19 10.6		20
Spike cleaning			51 283	12 445	34 196
<i>Potroom 1</i>					
Pot operating	20	79			
Alumina charging	33 17	63 55	83 39 22		
Crust breaking	26	49	14		
Beam raising		2,023	87	60	53
Spike pulling		561	141 976	71	316
Cleaning gas burners				1,597 1,436 16	1,185
<i>Potroom 2</i>					
Pot operating				36	77 55
Alumina charging	69	68		47 36	99
Spike pulling		3,274 914	2,360 818		
Cleaning cyclones & pipes			39	1,171 930 13	4,148

Table 3. (continued)

Job category	Exposure ($\mu\text{g PAH}/\text{m}^3$)				
	Day 1	Day 2	Day 3	Day 4	Day 5
<i>Potroom 3</i>					
Pot operating	32 11	83 156	65 79	5.9 35	104 106
Alumina charging	47	152	56		
Crust breaking				3.5	62
Spike pulling		147 380	350 87		
Cleaning gas burner		70	55	86 15	236

Fig 3 shows the ranges of total particulate PAH in the personal samples according to job types. The present administrative threshold limit value (TLV) of $40 \mu\text{g PAH}/\text{m}^3$ in Norway is indicated in the figure for comparison. As frequently observed in Söderberg plants, the spike-pullers had the highest exposure. In potroom 1, six samples showed variations from 300 to $1,600 \mu\text{g}/\text{m}^3$ with an arithmetic mean of $502 \mu\text{g}/\text{m}^3$. In potroom 2, seven samples showed values from 820– $4,150 \mu\text{g}/\text{m}^3$ with an arithmetic mean of $1,945 \mu\text{g}/\text{m}^3$. In potroom 3, where the spike-puller cabin is supplied with clean air, the exposure was somewhat lower. Eight samples showed values from 50 to $530 \mu\text{g}/\text{m}^3$ with an arithmetic mean value of $274 \mu\text{g}/\text{m}^3$. In all cases, however, the exposure was higher than $40 \mu\text{g PAH}/\text{m}^3$. It must be pointed out, however, that the reported values are not time-weighted averages over an 8-h shift as is the basis for the administrative value of $40 \mu\text{g PAH}/\text{m}^3$. A typical sampling period was 6 h.

Low exposure was found for foremen and tappers. Five samples for foremen showed exposure between 8 and $19 \mu\text{g}/\text{m}^3$, with one exception ($1,060 \mu\text{g}/\text{m}^3$). Sixteen samples of tappers showed values between 9 and $76 \mu\text{g}/\text{m}^3$. The arithmetic mean of $26 \mu\text{g}/\text{m}^3$ is well below the administrative TLV of $40 \mu\text{g}/\text{m}^3$. Most of the other occupations given in table 3 and fig 3 had values between those of the jobs already mentioned.

Fig 3. Concentration of total particulate polycyclic aromatic hydrocarbons in personal samples according to job type. (• = the geometric mean value for each job type, n = the number of samples analyzed)

Discussion

It is well known that certain PAH compounds exhibit a carcinogenic effect (8, 9). Less is known about the synergistic or antagonistic effects of the complex mixture of PAH encountered in the environment under study. In our subsequent discussion of occupational exposure, job variations and day-to-day variations, we have therefore limited ourselves to the total amount of PAH.

Occupational exposure

The American TLV for CTPV is 0.2 mg/m³ for benzene-soluble matter (1). PAH are a part of CTPV. The Norwegian administrative value for PAH in the aluminum industry is 40 µg PAH/m³, which corresponds to the previously cited TLV assuming 20% PAH in CTPV. This value is, however, a technical value and is not based on epidemiologic studies or a safety and health evaluation.

In this work, the personal samples collected represent most of the job categories in the potrooms and the anode plant. For all the job categories, samples were found with PAH concentrations at or above

40 µg/m³. However, for jobs such as the cleaning of cyclones and pipes, burner operating, foremen, tapping, and operating anode paste chargers, the arithmetic means were below the technical TLV of 40 µg/m³. Spikepullers, spikecleaners, gas manifold changers, pot liners, and beam raisers had the highest occupational exposure to PAH. For spikepullers, the geometric means in potrooms 1 and 2 were found to be higher than 400 µg/m³.

The anode paste plant is highly automated and occupational exposure is mainly connected to control and occasional repair. The personal exposure may therefore vary between wide ranges. Twelve samples showed values from 5 to

Table 4. One-way analysis of variance, with respect to different potrooms, for selected job categories. Due to the log/normal distribution the exposure data are expressed as log (µg PAH/m³). (PAH = polycyclic aromatic hydrocarbons)

Spike pulling

Variance source	Square sum	Degrees of freedom	F	(1-p) %
Potroom	2.84	2	16.33	99.99
Other	1.57	18		
Total	4.41	20		
Potroom 1	2.48	2.75	2.99	3.20
Potroom 2	3.52	3.37	2.96	2.91
Potroom 3	2.17	2.54	2.58	1.94
			3.07	3.16
			3.07	3.62
			2.73	1.93
				2.37
				2.58

Pot operating

Variance source	Square sum	Degrees of freedom	F	(1-p) %
Potroom	0.04	2	0.13	12.1
Other	2.21	15		
Total	2.24	17		
Potroom 1	1.30	1.90	1.92	
Potroom 2	1.84	1.83	1.56	1.88
Potroom 3	1.50	1.92	1.81	1.03
			1.74	1.84
			2.19	0.77
				2.02
				1.54
				2.0

Alumina charging

Variance source	Square sum	Degrees of freedom	F	(1-p) %
Potroom	0.15	2	1.06	61.8
Other	0.72	10		
Total	0.87	12		
Potroom 1	1.51	1.80	1.59	1.22
Potroom 2	1.56	1.67	2.00	1.74
Potroom 3	1.67	2.18	1.75	1.34
				2.03

Table 5. Two-way analysis of variance with respect to job type/person and day. (PAH = polycyclic aromatic hydrocarbons)

Variance source	Square sum	Degrees of freedom	F-ratio	(1-p) %
Job type/person	3.59	10	4.74	99.9
Day-to-day	0.40	2	2.62	90.2
Other	1.52	20		
Total	5.50			

Job type	Day 3 (log $\mu\text{g PAH/m}^3$)	Day 4 (log $\mu\text{g PAH/m}^3$)	Day 5 (log $\mu\text{g PAH/m}^3$)
Cleaning cyclones and pipes	1.59	1.11	1.24
Cleaning gas burners	1.42	1.21	1.41
Beam raising	2.15	1.85	2.50
Potroom work	1.74	1.48	1.63
Day work	1.73	1.50	1.67
Day work	1.45	1.57	1.79
Dust cleaning	1.97	1.46	2.17
Dust cleaning	1.91	1.66	1.81
Anode paste charging	1.71	1.08	1.53
Spike cleaning	2.45	2.65	2.29
Gas cleaning — day	1.08	1.90	2.37

1,200 $\mu\text{g/m}^3$ with a geometric mean of 87 $\mu\text{g/m}^3$. Generally, it should be pointed out that the observed values were measures of exposure of workers provided that no protective aids were used. Dust masks are extensively used, particularly for the more exposed jobs, such as spikepulling.

job categories and persons that demonstrated that even within the same job type the exposure may vary significantly. The difference between exposure on different days is shown on the 90 % significance level. The change in weather conditions that occurred during the sampling period may have caused the differences.

Statistical evaluations

One of the objectives of this project was to study the day-to-day variations of PAH exposure in the same job category and also the variations between job categories in the different potrooms. Table 4 shows the results of a one-way analysis of variance of job types with respect to the different potrooms. Significant differences were found only for the spikepullers. The spikepullers in potroom 3 had the lowest exposure, probably due to the air conditioned crane cabin.

A two-way analysis of variance was performed with respect to job type (with the exception of spikepullers), persons, and days, and the results are shown in table 5. The data were selected to include as many persons and job categories as possible. There was a significant difference between

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References

1. American Conference of Governmental Industrial Hygienists. Threshold limit values for chemical substances and physical agents in the workroom environment with intended changes for 1978. Cincinnati, OH 1978.
2. Bjørseth A. Analysis of polycyclic aromatic hydrocarbons in particulate matter by glass capillary gas chromatography. *Anal chim acta* 94 (1977) 21—27.
3. Bjørseth A, Bjørseth O, Fjeldstad PE. Kartlegging av polysykliske aromatiske hydrokarboner i arbeidsatmosfære. Teknisk-hygienisk rapport nr 1 (Characterization of polycyclic aromatic hydrocarbons in the working atmosphere. Report no 1). The Royal Norwegian Council of Scientific and Industrial Research, Oslo 1976. 64 p.
4. Bjørseth A, Bjørseth O, Fjeldstad PE. Polycyclic aromatic hydrocarbons in the work atmosphere: I. Determination in an aluminum reduction plant. *Scand j work environ health* 4 (1978) 212—223.
5. Bjørseth A, Bjørseth O, Fjeldstad PE. Polycyclic aromatic hydrocarbons in the work atmosphere: II. Determination in a coke plant. *Scand j work environ health* 4 (1978) 224—235.
6. Bjørseth A, Eklund G. Analysis for polynuclear aromatic hydrocarbons in working atmospheres by computerized gas chromatography-mass spectrometry. *Anal chim acta* 105 (1979) 119—128.
7. Bjørseth A, Lunde G. Analysis of the polycyclic aromatic hydrocarbons content of airborne particulate pollution as in a Søderberg paste plant. *Am ind hyg assoc j* 38 (1977) 224—227.
8. Committee on Biological Effects. Particulate polycyclic organic matter. National Academy of Science, Washington, DC 1972.
9. Dipple A. Polynuclear aromatic carcinogens. In: Searle CE, ed. Chemical carcinogens. American Chemical Society, Washington, DC 1976. (ACS monograph 173).
10. Doll R. Occupational lung cancer: A review. *Br j ind med* 16 (1979) 181—190.
11. Gibbs GW, Horowitz I. Lung cancer mortality in aluminum reduction plant workers. *J occup med* 21 (1979) 347—253.
12. Kipling MD. Soots, tars, and oils as causes of occupational cancer. In: Searle CE, ed. Chemical carcinogens. American Chemical Society, Washington, DC 1976. (ACS monograph 173).
13. Milham S. Mortality in aluminum reduction plant workers. *J occup med* 21 (1979) 475—480.
14. National Institute for Occupational Safety and Health. Criteria for a recommended standard... Occupational exposure to coal tar products. US. Government Printing Office, Washington, DC 1977. (DHEW (NIOSH) publication no 78—107).
15. Proctor NH. Medical surveillance planning for multiplant operations. In: Hughes JP, ed. Health protection in primary aluminum protection: Proceedings of a seminar, Copenhagen, 28—30 June 1977. International Primary Aluminum Institute, London 1978.
16. Tausch H, Stehlik G. Bestimmung Polycyclischer Aromaten in Russ Mittels Gas Chromatographie-Massenspektrometrie. *Chromatographie* 10 (1977) 350—357.

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