

# The Impact of Initial Job Assignment on Formaldehyde Exposure Among African-American and White Formaldehyde Industry Workers

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*We compared initial job assignments of African-American and white employees at eight worksites that used formaldehyde between 1940 and 1979. Unexposed workers were excluded. Median, ambient air formaldehyde, 8-hour, time-weighted average (TWA<sub>8</sub>) exposure estimates were determined for each worksite. Job assignments with TWAs above the worksite's median TWA<sub>8</sub> were called high formaldehyde exposed (HFE). Job assignments with TWAs less than or equal to the worksite's median TWA<sub>8</sub> for the same period were called lower formaldehyde exposed (LFE). Two worksites assigned black workers to HFE jobs in significantly higher proportions than white workers in some decades. One worksite assigned white workers in significantly higher proportions than black workers to HFE jobs in some decades. One worksite assigned racial groups in nearly equal proportions from 1940 to 1969. The remaining sites showed insignificant assignment disproportions ( $\alpha = 0.05$ ; Chi-square  $\leq 3.841$ , 1 degree of freedom) for any period. No major trend was apparent across all plants and decades. Am. J. Ind. Med. 34:57-64, 1998. © 1998 Wiley-Liss, Inc.<sup>†</sup>*

**KEY WORDS:** African-American; occupation; formaldehyde; exposure

## INTRODUCTION

In the last two decades, African-Americans (blacks) have endured a disproportionate disease burden in the United States [Walker et al., 1995; Reis et al., 1994; McWhorter et al., 1989; Terris, 1973]. To explain the burden, investigators cited differing lifestyles [Harris et al., 1993], biology [Cooper et al., 1981], and socioeconomic status [McWhorter et al., 1989]. Although hazardous environmental [Paustenbach, 1989; Miller, 1977; Cooper et al., 1981] and occupational [Checkoway et al., 1989] exposures may play a role, few investigations evaluated whether black

workers were disproportionately assigned to more hazardous occupational tasks than whites [Lloyd et al, 1970; Lloyd, 1971].

We used a large cohort study of formaldehyde industry workers to compare initial job assignment, exposure, and race in the workplace.

## METHODS

### Selection

A detailed description of the cohort selection is described elsewhere [Blair et al., 1986]. Briefly, composing the cohort were workers ( $n = 26,561$ ) first employed before January 1, 1966, at ten worksites (or plants) located in eight states (Connecticut, Massachusetts, New Jersey, New York, Ohio, South Carolina, Texas, and Wisconsin). This analysis excludes two worksites because one hired only one black worker and the other hired no black workers during the observation period. Furthermore, an additional 2,487 workers were excluded because their first job assignment was not formaldehyde-exposed; 18,038 workers remained.

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**TABLE I.** Racial Distribution by Plant and Formaldehyde Exposure Category for Workers First Assigned to Formaldehyde-Exposed Jobs From 1940–1970<sup>a</sup>

Worksite	Black			White		
	N	Workforce <sup>b</sup> percent	Racial group percent	N	Workforce percent	Racial group percent
1 Total	182	5	100	3424	95	100
HFE	86	5	47	1518	95	44
LFE	96	5	53	1906	95	56
2 Total	747	42	100	1014	58	100
HFE	66	43	9	86	57	8
LFE	681	42	91	928	58	92
3 Total	7	~1	100	905	99	100
HFE	7	1	100	690	99	76
LFE	0	0	0	215	100	24
4 Total	27	8	100	325	92	100
HFE	12	6	44	206	94	63
LFE	15	11	56	119	89	37
5 Total	128	3	100	4482	97	100
HFE	58	2	45	2295	98	51
LFE	70	3	55	2187	87	49
6 Total	157	5	100	3273	95	100
HFE	44	3	28	1541	97	47
LFE	113	6	72	1732	94	53
7 Total	62	4	100	1517	96	100
HFE	26	7	42	347	93	23
LFE	36	3	58	1170	97	77
8 Total	258	14	100	1530	86	100
HFE	157	22	61	569	79	37
LFE	101	10	39	961	90	63
All Plants						
Total	1568	9	100	16470	91	100
HFE	456	6	29	7252	94	44
LFE	1112	11	71	9218	89	56

<sup>a</sup>HFE = high formaldehyde-exposed; LFE = low formaldehyde-exposed.  
<sup>b</sup>Workforce = black worker + white workers.

### Exposure Assessment

Stewart et al. [1986] provide a detailed description of exposure estimate methods and measures. Formaldehyde levels were estimated for job titles recorded in employee personnel records using 1) air monitoring data gathered between 1983–84, 2) records of historical air monitoring performed by employees, 3) interviews of long-term workers, 4) reviews of historical production records, and 5) worksite visits.

**TABLE II.** First Assignment of Formaldehyde-Exposed Workers by Worksite, Racial Group, and Decade<sup>a</sup>

Worksite no. racial group	1st job with formaldehyde concentration		Chi square <sup>c</sup>	P value <sup>d</sup>
	> the median TWA <sup>b</sup> N (%)	≤ the median TWA N (%)		
Worksite No. 1				
≤1949				
Black	14 (64)	8 (36)	0.2	
White	755 (56)	591 (44)		
1950–1959				
Black	57 (51)	54 (49)	3.2	<0.07
White	651 (42)	894 (58)		
≥1960				
Black	15 (31)	34 (69)	1.9	
White	112 (21)	421 (79)		
Worksite No. 2				
≤1949				
Black	2 (29)	5 (71)	0.1	
White	3 (25)	9 (75)		
1950–1959				
Black	15 (05)	316 (95)	1.1	
White	16 (03)	529 (97)		
≥1960				
Black	49 (12)	360 (88)	1.1	
White	67 (15)	390 (85)		
Worksite No. 3				
≤1949				
Black	0 (0)	0 (0)	ND	
White	11 (50)	11 (50)		
1950–1959				
Black	2 (100)	0 (0)	1.0	
White	228 (60)	152 (40)		
≥1960				
Black	5 (100)	0 (0)	1.1	
White	451 (90)	52 (10)		
Worksite No. 4				
≤1949				
Black	2 (22)	7 (78)	2.9	<0.09
White	83 (57)	68 (43)		
1950–1959				
Black	6 (43)	8 (57)	0.5	
White	68 (75)	23 (25)		
≥1960				
Black	4 (100)	0 (0)	0.7	
White	55 (66)	28 (33)		
Worksite No. 5				
≤1949				
Black	0 (0)	0 (0)	ND	
White	572 (55)	462 (45)		

**TABLE II.** First Assignment of Formaldehyde-Exposed Workers by Worksite, Racial Group, and Decade (continued)<sup>a</sup>

Worksite no. racial group	1st job with formaldehyde concentration		Chi square <sup>c</sup>	P value <sup>d</sup>
	> the median TWA <sup>b</sup> N (%)	≤ the median TWA N (%)		
1950–1959				
Black	20 (47)	23 (53)	0.0	
White	1238 (52)	1157 (48)		
≥1960				
Black	38 (45)	47 (55)	0.2	
White	485 (46)	568 (54)		
Worksite No. 6				
≤1949				
Black	11 (14)	70 (86)	7.3	<0.01
White	441 (28)	1140 (72)		
1950–1959				
Black	28 (42)	41 (58)	7.3	<0.01
White	702 (58)	510 (42)		
≥1960				
Black	5 (71)	2 (29)	0.1	
White	398 (83)	82 (17)		
Worksite No. 7				
≤1949				
Black	0 (0)	0 (—)	ND	
White	12 (100)	0 (0)		
1950–1959				
Black	1 (10)	9 (90)	0.2	
White	77 (20)	305 (80)		
≥1960				
Black	25 (48)	27 (52)	15.8	>0.0001
White	258 (23)	865 (77)		
Worksite No. 8				
≤1949				
Black	86 (55)	70 (44)	0.1	
White	334 (47)	371 (53)		
1950–1959				
Black	71 (80)	18 (20)	72.0	<0.00001
White	227 (33)	466 (67)		
≥1960				
Black	0 ( )	13 (100)	0.1	
White	8 (6)	124 (94)		
All Worksites				
≤1949				
Black	115 (42)	160 (58)	1.7	
White	2211 (45)	2652 (55)		
1950–1959				
Black	200 (23)	469 (77)	101.7	<0.00001
White	3207 (44)	4036 (56)		

**TABLE II.** First Assignment of Formaldehyde-Exposed Workers by Worksite, Racial Group, and Decade (continued)<sup>a</sup>

Worksite no. racial group	1st job with formaldehyde concentration		Chi square <sup>c</sup>	P value <sup>d</sup>
	> the median TWA <sup>b</sup> N (%)	≤ the median TWA N (%)		
≥1960				
Black	141 (23)	483 (77)	89.1	<0.00001
White	1834 (42)	2530 (58)		

<sup>a</sup>First job assignment of workers to jobs with formaldehyde concentrations above (>) or below/equal to (≤) the worksite median TWA.

<sup>b</sup>Median based on TWA<sub>8</sub> of the first formaldehyde-exposed job weighted by the number of times the job occurred.

<sup>c</sup>Chi-square of independence of first job assignment and race ( $\alpha = .05$ ).

<sup>d</sup>P values: The probability that the observed chi-square value would result from the distribution of race and first job assignment ( $P > 0.05$ ; only P values < 0.1 shown).

ND = not determined.

## Statistical Analysis

Among formaldehyde-exposed jobs, a plant-specific median 8-hour, time-weighted average (TWA<sub>8</sub>) was derived from the first and longest job assignments from 1940–1979. Using the plant-specific median TWA<sub>8</sub>, worker assignments (jobs) were partitioned into two formaldehyde-exposed categories (i.e., greater than (high formaldehyde exposure, HFE) or less than or equal to (low formaldehyde exposure, LFE) the worksite median TWA<sub>8</sub>).

Two-by-two contingency tables were used to compare racial group proportional assignments to HFE and LFE jobs. A plant-specific  $\chi^2$  was derived using standard methods [Yates, 1934]. Statistical significance was achieved if the Chi-square was greater than 3.841 ( $\alpha = 0.05$  and 1 degree of freedom).

Worker job titles first assigned to HFE jobs were grouped into broader job categories reflecting similar processes, tasks, and/or departments. Assignment to an HFE job was defined as an event. HFE job assignment rates (JAR) were equal to:

JAR

$$= \frac{\text{Number of HFE jobs assigned for time } T}{\text{All formaldehyde exposed jobs assigned for time } T}$$

Race-specific JARs were derived for each worksite's broad job category by decade (time T). Dividing the JAR for blacks (JAR<sub>B</sub>) by the JAR for whites (JAR<sub>W</sub>) yielded the job assignment rate ratios (JARR):

$$\text{JARR} = \text{JAR}_B / \text{JAR}_W$$

Worksites' JARRs were calculated if 95% or more of the job titles for the first job assignment was known and five or more black workers were employed. Decade-specific ratios were omitted when few or no blacks were assigned formaldehyde-exposed jobs.

Similar analyses were used to examine longest-held jobs at selected worksites.

## RESULTS

Overall, 92% of all black workers and 88% of all white workers were assigned to formaldehyde-exposed jobs. Black workers represented about 7% of all workers ever assigned to formaldehyde-exposed jobs (not shown) and approximately 9% of all workers first assigned to a formaldehyde-exposed job (Table I). Formaldehyde TWA<sub>8</sub> estimates of 1 ppm or higher were observed at all plants except 2 and 6.

The racial composition of workers varied by worksite (Table I). Black workers represented 42% of Worksite 2's workforce, 14% of Worksite 8's, and less than 10% at all other sites. Among all worksites, 29% (456 of 1,568) of the black workers were first assigned to an HFE job compared to 44% (7,252 of 16,470) of the white workers ( $\chi^2 = 134$ ;  $P < 0.00001$ ). However, this varied by worksite. Worksites 4, 5, and 6 assigned a larger proportion of white workers to HFE jobs. Sites 3, 7, and 8 assigned a larger proportion of black workers. Sites 1 and 2 assigned similar proportions.

The proportion of racial groups among workers first assigned to formaldehyde-exposed jobs varied by decade (Table II). At Worksite 1, proportionally more black than white workers were first assigned to HFE jobs in all decades; worksites 2 and 5 show nearly equal proportions of both racial groups across all decades. Worksite 6 assigned proportionally more white workers than black workers to HFE jobs, particularly before 1960 ( $\chi^2 = 7$ ;  $P < 0.01$ ). In contrast, plant 7 assigned blacks to HFE jobs in significantly higher proportions than whites in earlier decades. When all eight worksites were examined collectively, white workers were assigned to HFE jobs as a first job at about 44% during every decade. For black workers, the proportion was 42% prior to 1950, but dropped to 23% in later decades.

White workers generally had longer job tenures than black workers, although these differences were small (Table III). Black and white workers at Worksite 4 worked for longer periods in all job categories (first, last, highest exposed, longest held) than all other plants. For these categories, differences in length of employment between black workers and white workers are statistically insignificant and show no obvious racial trend. Standard deviations suggested a wide range of years worked and/or, in reference to black workers, few data points.

Table IV summarizes JARRs and JARRs for first-job HFE assignments by decade and job category. This analysis

excludes Worksites 2–5 because too many first-job titles were unknown. At Worksite 1, black workers were assigned to "helper jobs" (any job with "helper" in the title) as a first job at a rate 80% higher (JARR = 1.8) than white workers from 1940–49. In contrast, JARRs at this worksite indicated that whites were assigned to laboratory jobs at rates of approximately 5 times (inverse of 0.2) more often than blacks in the 1940s. Resin production HFE jobs (extruder operator/packer, filter press operators, rolls testers, clean-up man, banbury, and still operators) were not assigned to black workers before 1960, but these jobs were assigned to whites at a rate 11% higher than black workers during the 1960s. Overall JARR analysis (1940–69) indicated that white workers were assigned to lab jobs at much higher rates than blacks and that blacks were assigned to helper jobs at rates 30% higher than whites. Whites were assigned to resin production jobs at a slightly higher rate than blacks.

At Worksite 6 during the 1940s and 1950s (Table IV), molding compound production jobs were first assigned to blacks at rates 4 and 3 times higher than whites workers, respectively. Since only one black worker was assigned to maintenance jobs in the 1960s, the rate estimate was highly unstable. This suggested that maintenance job assignment proportions for blacks and whites were reversed. Only one of 11 black workers was assigned to the maintenance department during the 1940s. Resin finishing jobs were assigned at near equal rates to both groups during the 1940s. White workers were assigned at more than twice the rates of black workers in the 1950s, while black workers were assigned at rates 70% higher than white workers in the 1960s. Overall, black workers were assigned at rates 2.6 times higher than whites to molding compound jobs. Black workers were not assigned to any other formaldehyde-exposed job categories at this worksite.

At Worksite 7 (Table IV), only two black workers were first assigned to an HFE job from 1940 to 1969. Black workers were assigned pilot plant, molding, maintenance, and miscellaneous jobs in rates 0.3, 0.4, 0.6, and 0.9 times that of white workers, respectively. At Worksite 8, blacks were assigned to process helper jobs at rates approximately twice those of white workers in the 1940s and 1950s. Laborer/worker jobs were assigned to blacks at rates approximately twice as high as white workers in the 1940s, but at nearly equal rates in the 1950s. Racial groups were assigned to resin jobs at similar rates in the 1940s, but black assignments dropped to 40% that of whites in the 1950s. Overall, from 1940 to 1969 process helper and laborer/worker jobs were assigned to blacks at rates nearly twice those of white workers; white workers were assigned to other jobs.

An analysis of workers involving their longest-held job was similar to findings for first-assigned jobs by race.

**TABLE III.** Years Spent in First, Last, Highest-Exposed, and Longest-Held Job Among Workers Whose First Job Assignment Exceeded the Worksite Median Eight Hour TWA by Worksite\*

	Worksite								All worksites
	1	2	3	4	5	6	7	8	
N	1,604	152	697	218	2,353	1,585	373	726	7,708
	Mean yrs (sd)								
First job									
Blacks	0.42 (1.20)	0.91 (1.26)	0.41 (0.42)	2.67 (4.84)	0.27 (0.35)	0.91 (1.41)	1.10 (2.36)	0.32 (0.45)	0.71 (1.42)
Whites	0.29 (0.82)	0.92 (1.52)	1.47 (2.37)	3.51 (5.88)	0.80 (2.15)	1.21 (2.93)	0.62 (1.27)	0.65 (1.60)	0.82 (2.20)
Last job									
Blacks	1.66 (2.22)	1.30 (2.14)	1.73 (2.02)	5.27 (3.89)	1.12 (2.79)	2.73 (5.00)	1.30 (1.32)	1.01 (1.89)	1.52 (2.71)
Whites	1.26 (2.28)	1.05 (2.00)	1.80 (2.09)	6.55 (6.04)	1.57 (3.00)	2.56 (4.78)	0.83 (1.51)	1.29 (2.43)	1.68 (3.25)
Highest-exposed job									
Blacks	0.53 (1.46)	0.88 (1.26)	1.07 (1.72)	4.10 (5.64)	0.35 (0.58)	1.08 (2.96)	1.30 (1.32)	1.01 (1.89)	0.82 (1.80)
Whites	0.36 (0.92)	0.84 (1.38)	1.50 (2.14)	4.22 (5.87)	0.78 (1.88)	1.25 (3.07)	0.83 (1.51)	1.29 (2.43)	0.88 (2.19)
Longest job									
Blacks	2.61 (2.81)	1.80 (2.36)	3.52 (4.46)	8.79 (4.32)	1.89 (2.91)	3.58 (5.65)	2.21 (2.80)	2.80 (3.47)	2.52 (3.45)
Whites	2.17 (3.19)	1.52 (2.32)	4.04 (3.3)	11.15 (6.21)	3.72 (4.55)	3.68 (5.37)	1.33 (2.24)	2.88 (3.53)	3.09 (4.31)

\*Mean years assigned and the standard deviation. No mean was calculated for Plant 9 because only one worker was hired. N = Worksite total number of white and black workers in first-assigned jobs exceeding the worksite's median formaldehyde 8-hour time-weighted average. First job = first job assigned. Highest-exposed job = job held with highest formaldehyde exposure. Longest job = longest held job.

## DISCUSSION

This investigation demonstrates that initial job assignments resulted in disproportionate formaldehyde exposures to white and black workers. Combining all plants, white workers were assigned in higher proportion to HFE jobs than blacks, but with considerable variation by plant and decade.

Lloyd and his co-investigators [1971] provided one of the clearest examples of disproportionate racial group assignment leading to differential exposure to job-related hazards. Our data show that disproportionate occupational exposures of black workers occurred following initial job assignment at some worksites. However, unlike the African-American steel industry workers, Lloyd observed, black formaldehyde industry workers, as a group, were initially assigned to lower formaldehyde-exposed jobs overall. At some worksites, we observed that white workers were initially assigned to HFE jobs in proportions higher than black workers were initially assigned. This indicated that patterns were plant-specific, and overall analyses were potentially misleading. For example, if individual worksites were not analyzed separately, statistically significant chi-squares show that whites were disproportionately exposed to HFE jobs throughout the 1950s and 1960s (Table II), where in reality the pattern varied by plant. An analysis of the relationship between

geography, exposure, and race would have been interesting; unfortunately, black worker populations in some geographic areas were too small to produce reliable estimates.

Of major concern was our need for information about factors confounding the relationship between exposure (initial job assignment) and race. Worker education levels [Digest of Education Statistics, 1995], skill requirements, national economic trends, regional traditions and/or customs (i.e., use of seasonal or migrant workers), and worksite preferences regarding racial group assignments may have been consequential. We, unfortunately, did not assemble this information.

Finally, information on racial differences in segmented labor markets [Boston, 1990; Carnoy and Rumberger, 1980] obtained by examining industrial shifts [Bound and Holzer, 1991] and earning levels [Levy and Mernane, 1992; Bound and Freeman, 1992] might have helped us to identify other potential confounders. Studies investigating changes in United States job structure quality, based on earnings, working conditions, job advancement, work rules, and employment stability [Moss and Tilly, 1991; Gittleman and Howell, 1995] may also have contributed to our knowledge of factors affecting associations between job assignment and race.

In conclusion, larger studies incorporating these elements may lead to a better understanding of the relationship

**TABLE IV.** Number of HFE Job Assignments, HFE Job Assignment Rate (JAR), HFE Job Assignment Rate Ratio (JARR), and Overall Job Assignment Rate Ratio for Selected Worksites and Jobs

	HFE assignments			HFE job assignment rate (JAR)			HFE rate ratio (JAR <sub>B</sub> /JAR <sub>W</sub> )			Rate ratio overall
	1940-49	1950-59	1960-69	1940-49	1950-59	1960-69	1940-49	1950-59	1960-69	1940-69
Worksite 1										
First job title										
Helper										
Black	13	57	11	92.9	100.0	73.3	1.8	1.1	1.2	1.3
White	414	602	69	54.8	92.5	61.6				
Lab										
Black	1	0	0	7.1	—	—	0.2	—	—	0.1
White	332	45	7	43.9	6.9	6.3				
Resin production										
Black	0	0	4	—	—	26.7	—	—	0.9	0.9
White	7	4	35	0.9	0.6	31.3				
Worksite 6										
First job title										
Molding compound										
Black	7	22	1	63.6	78.6	20.0	4.0	2.9	0.5	2.6
White	65	192	121	15.9	27.4	40.7				
Maintenance dept										
Black	1	0	0	9.1	—	—	0.5	—	—	0.5
White	31	0	0	17.6	—	—				
Resin finishing										
Black	3	6	4	27.3	21.4	80.0	1.1	0.5	1.7	0.7
White	103	329	139	25.3	46.8	46.8				
Worksite 7										
First job title										
Pilot plant										
Black	0	0	3	—	—	12.0	—	—	0.2	0.3
White	0	0	125	—	—	48.5				
Molding										
Black	0	1	1	—	100.0	4.0	—	1.1	—	0.4
White	5	69	0	41.7	89.6	—				
Maintenance										
Black	0	0	5	—	—	20.0	—	—	0.6	0.6
White	2	4	90	16.7	5.2	34.9				
Miscellaneous										
Black	0	0	2	—	—	8.0	—	—	0.9	0.9
White	5	4	21	41.6	5.2	8.1				
Worksite 8										
First job title										
Process helper										
Black	39	50	0	45.0	70.4	—	1.9	2.4	—	2.2
White	81	67	0	24.2	29.5	—				
Laborer/worker										
Black	34	9	0	39.5	12.7	—	2.5	0.9	—	1.9
White	53	31	0	15.9	13.6	—				

**TABLE IV.** Number of HFE Job Assignments, HFE Job Assignment Rate (JAR), HFE Job Assignment Rate Ratio (JARR), and Overall Job Assignment Rate Ratio for Selected Worksites and Jobs (continued)

	HFE assignments			HFE job assignment rate (JAR)			HFE rate ratio (JAR <sub>B</sub> /JAR <sub>W</sub> )			Rate ratio overall
	1940–49	1950–59	1960–69	1940–49	1950–59	1960–69	1940–49	1950–59	1960–69	1940–69
Resinimenes										
Black	4	5	0	4.6	7.0	—	1.0	0.4	—	0.5
White	15	44	3	4.5	19.4	37.5				
Miscellaneous										
Black	9	7	0	10.5	9.9	—	0.5	1.2	—	0.6
White	69	30	1	20.7	13.2	12.5				

HFE—jobs with formaldehyde exposure above worksite median TWA. Job titles do not appear if no black workers were assigned to those job titles. No black workers were assigned in the above categories before 1940 or after 1969 (not shown on table). No rate estimates were derived for the 1970s because no black workers were hired in the 1970s. The total number of white workers typically does not reflect the entire HFE job population because all job titles are not shown. Denominators for the HFE assignment rates can be obtained from HFE jobs assigned for each decade in Table I.

between racial group membership, job assignment, and subsequent hazardous exposure in the United States.

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