Applied Occupational and Environmental Hygiene
Volume 16(2): 263–270, 2001
1047-322X/01 $12.00 + .00

Time Trends in Exposure Measurements from OSHA Compliance Inspections of the Pulp and Paper Industry

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Time trends in employee exposures to the air contaminants measured by the Occupational Safety and Health Administration (OSHA) during compliance inspections of pulp and paper manufacturing facilities conducted between 1979 and 1997 were evaluated based on the measurement results stored in the OSHA Integrated Management Information System (IMIS) database. The IMIS database is among the largest sources of occupational exposure measurements available for occupational health research in the United States. The IMIS database contains the results of 3568 personal time-weighted average (TWA) measurements for 171 air contaminants made at 524 establishments in Standard Industrial Classification (SIC) 26. An analysis of these measurements revealed an overall decrease in the total number of measurements made per year since 1991, and a decrease in the percentage of measurements by year that exceeded the OSHA permissible exposure limits (PELs). Linear regression analyses detected decreasing trends in the geometric mean concentrations by year for 33 of the 36 agents analyzed.

Keywords OSHA IMIS, Pulp and Paper, Time Trends Exposure

Time trends in exposure to air contaminants are an important consideration for exposure assessment in occupational health research. Occupational epidemiology studies of chronic diseases with long latency periods frequently use cumulative exposure, calculated as the product of exposure intensity and duration, as a quantitative metric to detect associations between exposure and disease.[1] When cumulative exposures are calculated over several decades of employment, adjustment for time trends in occupational exposure levels can improve the accuracy of exposure assessments and the detection of exposure-response relationships.[2–4]

As part of an occupational epidemiological investigation, a retrospective exposure assessment was conducted for a cohort of workers employed in the pulp and paper industry between 1940 through 1991.[5] The pulp and paper industry is one of the largest and oldest industries in the United States, and many of the mills built in the early to mid-1900s are still in operation.[6] The promulgation of environmental and occupational safety and health regulations in the 1970s resulted in the installation of pollution controls that reduced the emissions of air contaminants from pulp and paper manufacturing processes.[7] Anecdotal evidence from interviews with long-term employees and industry experts suggested that worker exposure levels decreased significantly over that time period.

Workers at pulp and paper manufacturing facilities are potentially exposed to a variety of air contaminants for which the Occupational Safety and Health Administration (OSHA) has conducted exposure monitoring to assess compliance with permissible exposure limits (PELs). The results of these exposure measurements are stored in the OSHA Integrated Management Information System (IMIS) database. The IMIS database has been suggested as a potential source of information to characterize exposure levels for retrospective exposure assessment[8] and occupational health surveillance programs.[9–10] The objective of this investigation was to summarize the results of the measurements contained in the OSHA IMIS database, and to evaluate time trends in the measurement results for selected agents from the pulp and paper industry.

METHODS

Time trends in worker exposure to air contaminants at pulp and paper manufacturing facilities were evaluated using the exposure measurements made by OSHA during compliance inspections conducted between 1979 and 1997.[11] The data analyzed were obtained from OSHA in a report containing all

monitoring results for SIC 26 contained in the IMIS database. For each inspection, the report included the name, address and four-digit SIC code of the establishment; the type of inspection (complaint, planned, referral, follow-up); the dates on which the inspection was conducted; and the results of the exposure measurements taken during the inspection. For each measurement, the report included the name and IMIS code number of the agent monitored; the type of measurement (area or personal); the duration of the measurement (time-weighted average, TWA; or short-term exposure level, STEL); the job title for personal samples or the sample site for area measurements; the air concentration measured, and the concentration units. A severity factor calculated as the measured concentration divided by the applicable OSHA PEL was provided, along with a citation number, if issued.

To evaluate trends in the frequency of sampling activity, the number of inspections were tallied by year. The inspections were grouped into three categories based on the reason for the inspection as indicated in the database: complaint, planned, or other. Complaint inspections are typically initiated by an employee request, while planned inspections are initiated by a random selection process. The total number of personal TWA measurements and the number of measurements that detected exposures above the PEL for all agents monitored were tallied by year.

To evaluate time trends in the concentrations measured for specific agents, linear regression analyses of geometric mean concentration by year were conducted. These analyses were restricted to the 36 agents for which the database contained at least six measurements above the limit of detection (LOD) made during three or more years with two or more measurements per year. For the purposes of the time trend analysis, a value equal to the estimated LOD was substituted for measurements reported as "n/d," that is, not detected. The values for the LOD were estimated based on the analytical detection limits of the OSHA methods for each of the agents, assuming maximum recommended sample volumes.

The values of the log-transformed concentrations were regressed on year to determine the percent change in the geometric mean concentration by year over the time period during which measurements were made. The use of a log-linear model assumes that the concentrations changed by a constant percentage each year rather than a fixed amount (e.g., by 10% per year rather than by 10 ppm per year). The confidence intervals for the regression coefficients were used to test the hypothesis that employee exposure levels have decreased over the time period for which OSHA monitoring results are available.

The analysis of time trends was conducted for the personal TWA measurements by agent aggregated without regard to the four-digit SIC or job title. Additional analyses by job title and four-digit SIC were conducted for the three agents with the largest number of personal TWA measurements: particulates not otherwise regulated (PNOR), toluene, and carbon monoxide. The number of measurements by four-digit SIC group and by job title were tallied to identify subgroups with at least six measurements, and to compare the trends in the subgroups with the overall trend for these agents.

RESULTS

The IMIS report contained the results of 9933 measurements made during 1508 inspections at 1206 establishments from SIC 26 conducted between 1979 and 1997. Of these measurements, 3568 were personal TWA measurements for 171 different air contaminants. The IMIS database also contained 482 short-term measurements, 1377 area or screening measurements, 4283 noise measurements, and 222 bulk sample or wipe measurements which were not included in this analysis (Table I).

The measurements were made at establishments from each of the 17 four-digit SIC groups included in SIC 26.[12] The largest number of measurements, 30 percent were made in SIC 2621, paper manufacturing facilities, followed by SIC 2679, converted paper products facilities with 15 percent, and SIC 2672, paper-coated and laminated packaging facilities with 12 percent, while the remaining four-digit SICs had less than 10 percent each (Table II).

The frequency of inspections and the number of measurements per year peaked in 1991. The number of OSHA inspections conducted in SIC 26 during which one or more personal TWA measurements were made increased from 26 in 1979 to 57 in 1991, and then decreased to 18 in 1997 (Figure 1). Overall, 62 percent of inspections were classified as complaint, increasing from a low of 45 percent in 1983 to a high of 85 percent in 1996. The number of personal TWA measurements by year

TABLE I

Descriptive statistics for OSHA IMIS database for SIC 26: paper and allied products from 1979 to 1997

Number of inspections:	1508
w/Personal TWA measurements	613
Number of establishments inspected:	1206
w/Personal TWA measurements	524
Number of measurements:	9933
Personal TWA	3568
Personal STEL/Ceiling	482
Area/screening	1377
Bulk/wipe	222
Noise/heat	4283
Number of agents with personal TWA	171
Measurements:	
w/100% <LOD	54
w/one or more >LOD and 100% <PEL	85
w/one or more >PEL	32
w/two or more >LOD in 3 or more years	36

TWA = Time-Weighted Average.
STEL = Short-Term Exposure Limit.
LOD = Limit of Detection.
PEL = Permissible Exposure Limit.

TABLE II
Number of personal TWA measurements by four-digit SIC code

SIC	Products	N	%
2611	Pulp mills	145	4
2621	Paper mills	1051	30
2631	Paperboard mills	236	7
2652	Setup paperboard boxes	16	<1
2653	Corrugated and solid fiber boxes	291	8
2655	Fiber cans, drums, and similar products	92	3
2656	Sanitary food containers	15	<1
2657	Folding paperboard boxes	294	8
2671	Paper-coated and laminated, packaging	72	2
2672	Paper-coated and laminated, n.e.c.	445	12
2673	Bags: plastics, laminated, and coated	174	5
2674	Bags: uncoated paper and multiwall	5	<1
2675	Die-cut paper and board	55	2
2676	Sanitary paper napkins	65	2
2677	Envelopes	53	1
2678	Stationary products	28	1
2679	Converted paper products, n.e.c.	531	15
Total		3568	

n.e.c. = not elsewhere classified.

peaked at 350 in 1991 and then decreased through 1997, when only 60 personal TWA measurements were made (Figure 2). The average number of personal TWA measurements per inspection across all years was 5.2, with a range of 3.3 to 9.0 with no evident trend over time.

For 54 (32%) of the 171 agents monitored by OSHA, all personal TWA measurements were below the LOD. For 85 (50%) of the agents, there was at least one measurement above the LOD, but no measurements above the PEL. One or more measurements above PEL were reported for 32 (19%) of the 171 agents monitored (Table III). The percentage of measurements above the PEL decreased from 16 percent in 1980 to 8 percent in 1997 (Figure 2). No measurements above the PEL were reported in 1994, the only year in which this occurred.

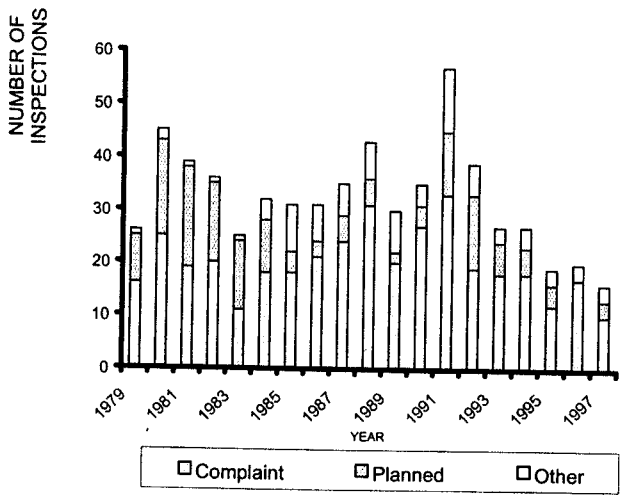

FIGURE 1
Number of OSHA inspections by year and type in SIC 26.

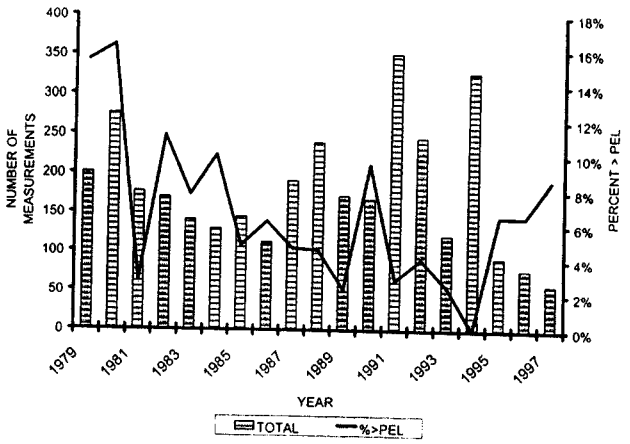

FIGURE 2
Number and percent of personal TWA exposure measurements above the OSHA PEL by year.

Based on the linear regression analyses, decreasing trends in the geometric mean of the exposure measurements were seen over time for 33 of the 36 agents (92%), with statistically significant decreases for 14 of the 36 agents (39%). Time trends by type of agent were evaluated by grouping the 36 agents into four categories: solvents (n = 18), metals (n = 4), gases (n = 5), and dusts/mists (n = 9). Decreasing trends were seen for 17 of the 18 solvents, for 3 of the 4 metals, for 4 of the 5 gases, and for all 9 of the dusts/mists (Table IV).

To demonstrate the regression method used to evaluate time trends and to provide a visual representation of the measurements, the 224 carbon monoxide personal TWA measurements from the database are shown plotted on a log scale against year in Figure 3. A straight line to represent the time trend is fitted through the data points using a linear regression of the log-transformed values on year. The coefficient for year from the regression equation displayed at the bottom of the figure corresponds to the slope of the line and indicates an annual decrease of 6 percent in the geometric mean concentration over the time period from 1979 to 1997. A 6 percent reduction per year resulted in an approximately three fold decrease in the geometric mean exposure from 48 ppm in 1979 to 15 ppm in 1997.

The dashed line drawn through the concentration values on Figure 3 is the running average of the log-transformed measurement values. The agreement between the running average line and the regression line can be used to assess the assumption of a linear decrease in the logarithm of the concentration over time. In this case, the two lines appear parallel and close together, indicating that the assumption of a linear decrease appears valid.

TABLE III

Summary statistics for 32 agents with one or more personal TWA measurements above the PEL

Agent	PEL	Units	N	% <LOD	% >PEL	AM	GM	Max
Particulates NOR (Total)	15	mg/m^3	293	3	10	5.5	1.2	106
Toluene	200	ppm	225	22	1	21	5.4	440
Carbon monoxide	50	ppm	224	3	26	42	24	600
Asbestos (all forms)	0.1	f/cc	179	68	11	0.40	0.02	32
2-Butanone	200	ppm	176	37	6	66	5.9	910
Particulates NOR (Resp)	5	mg/m^3	152	5	20	3.2	0.47	30
Formaldehyde (before 1988)	3.0	ppm	24	33	0	0.04	0.02	0.4
Formaldehyde (after 1987)	0.75	ppm	120	26	1	0.16	0.07	0.85
Ethyl acetate	400	ppm	108	44	1	36	1.9	1400
Xylene (all isomers)	100	ppm	76	46	1	9.8	0.82	147
Hexone	100	ppm	67	30	3	18	6.5	253
Lead, inorganic	0.05	mg/m^3	61	80	2	0.007	0.002	0.25
Sulfur dioxide	5	ppm	56	23	7	1.3	0.21	9.3
Methyl Chloroform	350	ppm	38	32	3	47	6.0	1006
Methyl Alcohol	200	ppm	33	21	15	88	20	559
Copper fume	0.1	mg/m^3	32	63	6	0.011	0.002	0.14
Lead arsenate	0.01	mg/m^3	29	24	69	0.03	0.02	0.16
Silica, Crystalline (Resp.)	[A]	mg/m^3	23	65	4	1.7	0.05	30
Cyclohexanone	50	ppm	21	33	10	25	2.9	388
Welding fumes (total)	5	mg/m^3	15	0	7	2.7	1.4	18
Naphtha (coal tar)	100	mg/m^3	14	36	21	76	56	301
Methylene Chloride	25	ppm	13	8	31	87	16	730
Cellulose (total dust)	15	mg/m^3	12	0	33	14	3.7	46
Ozone	0.1	ppm	12	58	8	0.10	0.05	0.80
Paraffin wax fume	2	mg/m^3	9	22	11	0.61	0.13	2.9
Carbon Tetrachloride	10	ppm	8	88	13	3.1	1.4	18
Borates, tetra, sodium salts	15	mg/m^3	7	0	14	4.7	1.4	19
Calcium oxide	5	mg/m^3	5	40	20	4.2	2.6	13
Copper dusts & mists	1	mg/m^3	3	0	33	0.65	0.10	1.9
Coal tar pitch volatiles	0.2	mg/m^3	2	50	50	0.37	0.25	0.64
Trichloroethylene	100	ppm	1	0	100	150	150	150
Acetonitrile	40	ppm	1	0	100	58	58	58
Hydrogen fluoride	3	ppm	1	0	100	4.8	4.8	4.8

N = number of measurements, AM = arithmetic mean, GM = geometric mean, MAX = maximum, PEL = Permissible Exposure Limit, LOD = Limit of Detection.

[A]PEL for respirable crystalline silica = $10\ mg/m^3/(2+\ \%SiO_2)$.

A similar analysis of the formaldehyde measurements revealed that a significant reduction in the geometric mean occurred after the PEL was lowered from 3.0 ppm to 0.75 ppm in 1987. The number of measurements per year increased in 1988, while the annual geometric mean of the measurements between 1988 and 1997 decreased an average of 17 percent per year (Table V).

An analysis of time trends by job title was not conducted, since the job titles in the database were not standardized and included abbreviations for the names of specific equipment which made grouping on job title problematic. For example, the 293 measurements for PNOR included 141 different job titles, of which only 9 had 6 or more measurements. The 225 toluene measurements included 56 job titles, of which 8 had 6 or more measurements. The 224 carbon monoxide measurements included 78 job titles of which only 3 had 6 or more measurements.

An analysis of the toluene measurements by four-digit SIC code was conducted and indicated large differences in the number of measurements and in the direction of the time trends between the four-digit SIC groups. A time trend analysis was conducted for 7 of the 12 groups for which there were a sufficient number of samples. Statistically significant trends were detected in five of the seven groups, with three groups decreasing and two groups increasing (Table VI).

TABLE IV
Time trends in geometric mean concentration by agent

Agent name	N	Initial year	GM_i	Final year	GM_f	Annual trend	95% CI
Solvents (ppm)							
Toluene	225	1979	8.4	1996	2.7	−6%	(−12%, −1%)[A]
2-Butanone	176	1979	11.5	1994	2.4	−10%	(−18%, −1%)[A]
Ethyl acetate	108	1979	3.2	1994	0.79	−9%	(−18%, 2%)
Isopropyl alcohol	80	1979	4.8	1997	2.2	−4%	(−15%, 8%)[A]
Xylene (all isomers)	76	1979	2.2	1994	0.3	−12%	(−22%, −2%)[A]
Hexone	67	1979	10.1	1994	2.5	−9%	(−16%, −2%)[A]
Ethyl alcohol	64	1979	8.1	1994	0.83	−12%	(−20%, −4%)[A]
Petroleum distillates	53	1979	6.1	1995	1.1	−10%	(−20%, 1%)
Acetone	42	1980	21.2	1995	2.3	−14%	(−23%,−4%)[A]
Hexane (n-Hexane)	40	1980	116	1995	1.9	−24%	(−33%, −14%)[A]
Isopropyl acetate	38	1979	14.1	1993	1.1	−17%	(−25%, −7%)[A]
Methyl chloroform	38	1979	8.6	1996	3.8	−5%	(−16%, 8%)
N-Propyl acetate	38	1980	3.1	1994	1.7	−4%	(−23%, 19%)
Methyl alcohol	33	1979	54	1996	13	−8%	(−21%, 7%)
Propyl alcohol	30	1980	3.1	1994	1.7	−4%	(−23%, 19%)
Stoddard solvent	23	1981	0.8	1995	2.4	8%	(−6%, 24%)
Cyclohexanone	21	1979	12.8	1994	0.78	−17%	(−26%, −7%)[A]
Methylene Chloride	13	1982	80	1996	4.3	−19%	(−39%, 8%)
Metals (mg/m^3)							
Lead, inorganic (as Pb)	61	1979	0.003	1996	0.001	−7%	(−12%, −1%)[A]
Iron oxide fume	43	1979	0.21	1996	0.03	−11%	(−27%, 8%)
Chromium	42	1979	0.002	1996	0.003	4%	(−9%, 18%)
Welding fumes (total)	15	1980	2.1	1992	0.7	−9%	(−20%, 4%)
Gases (ppm)							
Carbon monoxide	224	1979	48.2	1997	14.6	−6%	(−9%, −4%)[A]
Formaldehyde (all)	144	1980	0.06	1997	0.06	0%	(−5%, 7%)
Formaldehyde (after 1987)	120	1988	0.12	1997	0.02	−17%	(−25%, −10%)[A]
Sulfur dioxide	56	1979	0.37	1997	0.09	−8%	(−18%, 4%)
Acrolein	21	1985	0.005	1994	0.009	6%	(−1%, 13%)
Ammonia	17	1979	8.7	1997	2.2	−7%	(−16%, 2%)
Dusts and mists (mg/m^3) or (f/cc)							
Particulate NOR (total)	293	1979	2.1	1997	0.8	−5%	(−9%, −1%)[A]
Asbestos (all forms)	179	1979	0.022	1996	0.010	−5%	(−10%, 1%)
PNOR (resp)	152	1979	1.3	1997	0.08	−14%	(−19%, −10%)[A]
Sodium hydroxide	27	1980	0.019	1997	0.008	−5%	(−19%, 11%)
Phenol	24	1982	0.085	1995	0.061	−2%	(−11%, 7%)
Silica, crystalline, (resp)	23	1979	0.098	1996	0.019	−9%	(−27%, 14%)
Wood dust	23	1979	1.4	1994	0.5	−6%	(−18%, 7%)
Coat dust	18	1979	0.43	1993	0.17	−7%	(−17%, 6%)
Oil mist, mineral	18	1980	1.0	1994	0.3	−7%	(−17%, 3%)

N = number of measurements, GM_i = geometric mean for initial year, GM_f = geometric mean for final year, [A] = upper 95% confidence limit <0% per year.

DISCUSSION

Several studies have looked at the OSHA IMIS database to characterize past exposures and to evaluate time trends in exposure for various agents and SIC group. A study conducted to characterize lead exposures used IMIS data from OSHA inspections conducted between 1980 and 1985 detected no significant change during this six-year period in the percentage of measurements that exceeded the PEL.[9] Another investigation conducted using IMIS data from 1979 to 1989 found decreases of 5 to 9 percent per year in lead exposures and decreases of

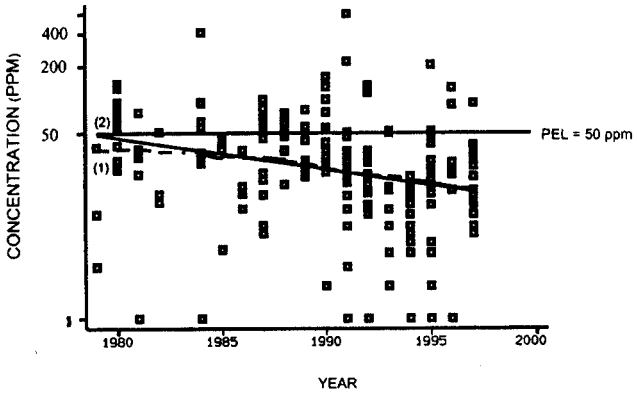

FIGURE 3
Time trend analysis of carbon monoxide personal TWA measurements.

7 percent per year in perchloroethylene exposures, but no evidence of changes over time in exposure to welding fume or iron oxide.[10] Neither of these studies included facilities from SIC 26; however, both concluded that the IMIS database is amenable to time trend analysis. A study of wood dust exposure based on the IMIS database from a range of industries, including SIC 26, found that exposure levels decreased from a geometric mean of 4.59 mg/m^3 in 1979 to 0.14 mg/m^3 in 1997, a reduction of approximately 7 percent per year.[14]

Decreasing trends in occupational exposure-based databases other than the IMIS database have also been reported. A recent study of time trends in exposure to inhalable particulate in the rubber industry in the Netherlands detected an average annual decrease of 5.7 percent per year between 1988 and 1997 that was attributed to implementation of engineering controls.[15] An evaluation of trends in occupational exposure based on a review of published literature found most exposures declined between 4 percent and 14 percent per year, with a median value

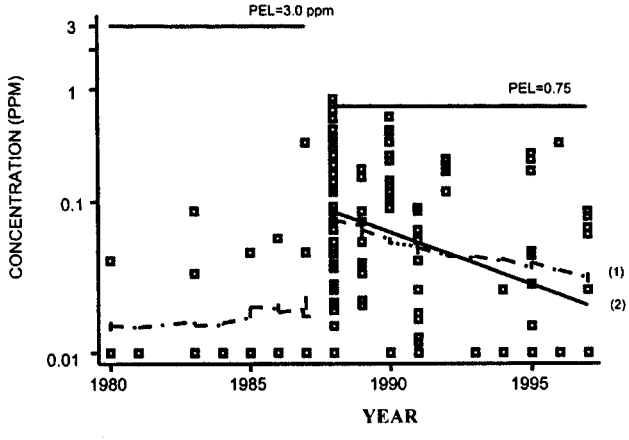

FIGURE 4
Time trend analysis of formaldehyde personal TWA measurements.

of 8 percent.[3,4] These results are consistent with the trends in occupational exposure levels found in this study, and suggest that reductions of 5 to 10 percent per year appear plausible.

While the IMIS database may be useful for retrospective exposure assessment, several potential biases exists that could affect the reliability of exposure estimates based on the IMIS database. These measurements are not random samples, and cannot necessarily be assumed to represent the average exposures across an entire industry. OSHA inspectors conduct exposure monitoring primarily to evaluate compliance with PELs, and thus tend to monitor more often when they suspect that exposures are above the PEL.[11] Therefore, the geometric means of the OSHA measurements might overestimate the actual exposures for the population not sampled, and the extent to which the time trends observed in the OSHA measurements can be generalized to employees not monitored is not known.

For the purposes of the time trend analysis, the personal TWA measurements were grouped by agent for all four-digit SIC and job titles. This broad aggregation provided a larger number of measurements for the statistical analysis of trends by agent, but it also introduced a potential problem for interpretation of time trends. The same jobs and same types of facilities were not monitored each year, so that time trends for some agents could be due to differences in the type of facilities monitored rather than a systematic change over time. For example, while the overall trend for the toluene measurements was decreasing, decreasing

TABLE V
Personal TWA formaldehyde measurements by year

Year	N	N > LOD	GM	GSD
1980	6	2	0.01	—
1981	1	0	0.01	—
1982	0	—	—	—
1983	3	2	0.04	—
1984	2	0	0.01	—
1985	3	1	0.02	—
1986	5	0	0.01	—
1987	4	3	0.05	5.0
1988	39	37	0.13	3.6
1989	14	14	0.10	2.4
1990	17	14	0.14	3.8
1991	14	10	0.03	2.7
1992	5	5	0.25	1.3
1993	3	0	0.01	—
1994	8	3	0.01	1.7
1995	8	7	0.07	3.8
1996	2	1	0.06	—
1997	10	6	0.03	3.1
Total	144	105	0.06	4.2

N = Number of measurements; LOD = Limit of detection; GM = Geometric mean concentration; GSD = Geometric standard deviation.

TABLE VI
Summary statistics and time trends for toluene personal TWA measurements by four-digit SIC code

Four-digit SIC	N	GM	GSD	Years	Annual trend
2621	5	14.3	13.3	4	—
2631	11	6.6	8.6	4	11%
2653	18	2.5	8.0	7	−25%[A]
2655	11	11.0	7.4	5	−21%[A]
2656	1	10.0	1.0	1	—
2657	15	7.7	9.0	4	92%[A]
2671	12	4.7	10.1	2	—
2672	92	5.6	6.6	12	−13%[A]
2673	18	2.4	7.8	3	−3%[A]
2677	4	10.6	1.6	1	—
2678	1	2.4	1.0	1	—
2679	37	6.2	5.2	8	39%[A]
Total	225	5.4	7.0	18	−6%

[A] = $p < 0.05$.
N = number of measurements; GM = geometric mean; GSD = geometric standard deviation.

trends were seen in three of the groups and increasing trends were seen in two others (Table VI).

Another limitation of the OSHA database relates to the high percentage of measurements reported as n/d for some agents, with some as high as 80 percent for lead. Since a non-zero value is required for the log-transformation used to analyze time trends, these measurements were included through substitution of the estimated LOD for the censored measurements. The substitution of the LOD value for censored values will result in a small positive bias in the geometric mean concentrations.

The formaldehyde measurements are used to demonstrate a limitation in the use of a linear model to represent time trends in exposures. The geometric mean of the formaldehyde measurements decreased 17 percent per year from 1988 through 1997. Unlike the carbon monoxide measurements, however, in which the reduction by year was relatively constant over the time period monitored, the formaldehyde measurements appear to follow more of a step change pattern. The magnitude of the reduction was not constant by year, but, instead, was larger in the four years after 1988, after which the annual change becomes smaller. Thus, the regression line fitted to the measurements underestimates exposures in 1997 and overestimates exposures prior to 1987 compared to the actual measurements taken. Both the numbers of measurements as well as the geometric mean of the measurements increased dramatically in 1988 compared to previous years. The geometric mean of the 24 measurements made between 1980 and 1987 was 0.03 ppm, while the geometric mean of the 39 measurements in 1988 was 0.13 ppm. It seems unlikely that exposures would have increased four-fold with promulgation of the formaldehyde standard, and, therefore, the relatively small number of measurements prior to 1988 may have underestimated exposures during that period (Table V).

The OSHA PELs for asbestos and lead were reduced during the time period in which measurements were collected, but the decreasing trends in the measurements for these agents were not as substantial as the decrease in the formaldehyde measurements. In 1986, the PEL for asbestos was reduced from 2.0 f/cc to 0.2 f/cc. Although a 5 percent decreasing trend was seen for asbestos, the trend was not statistical significant, in part because the exposures were low compared to the PEL, and 68 percent of the measurements were below the limit of detection.

The OSHA PEL for lead was reduced to 50 $\mu g/m^3$ in 1979, but the effective date was delayed and did not become effective for all industry sectors until 1995. A decreasing trend of 7 percent per year was seen for lead exposure concentrations between 1979 and 1997. Again, the concentrations measured were low relative to the PEL, and 80 percent of the samples were below the limit of detection. Only one of the 61 personal TWA measurements detected a lead exposure above the current PEL.

CONCLUSIONS

The IMIS database contains measurements for a wide variety of air contaminants from pulp and paper manufacturing facilities. Since 1979, OSHA inspectors measured occupational exposure to 85 agents, with 32 agents having one or more measurement above the PEL. OSHA exposure monitoring in the pulp and paper industry decreased substantially during the 1990s, as demonstrated by the downward trends in the number of compliance inspections and the number of measurements taken since 1991.

The frequency of exposures above the PEL measured by OSHA decreased from 16 percent in 1979 to 8 percent in 1997, and the geometric mean of the measurements has decreased for the 33 of the 36 agents analyzed. The decreasing trends in the geometric mean concentrations suggest that occupational exposures to most of the air contaminants monitored by OSHA in the pulp and paper industry have decreased since 1979. Reductions of between 5 percent and 6 percent per year in the geometric mean were seen for the three agents with over 200 measurements (PNOR, toluene, and carbon monoxide), and statistically significant decreasing trends ranging from 7 percent to 24 percent were seen for 11 other agents. For 19 of the agents analyzed, decreasing trends between 4 percent and 19 percent per year were observed, but the trends were not statistically significant. Due to the use of a log-linear model to estimate time trends and the small number of measurements for some agents, the values of the geometric means and the magnitude of the decreases in Table IV could be overestimated, in which case these values would represent upper estimates.

One of OSHA's mandates is the prevention of occupational illnesses and diseases. The impact of OSHA regulations on the incidence rates of occupational illness is difficult to assess, however, particularly for chronic diseases with long latency periods

for which the information needed to calculate incidence rates in exposed workers is not generally available. The reduction of occupational exposures subsequent to promulgation of a new occupational safety and health standard provides some indication to evaluate reduction in disease risk in lieu of incidence rates. The findings from this study support the assumption that, in general, occupational exposures to many of the air contaminants in the pulp and paper industry have decreased over the last two decades.

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