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ORIGINAL RESEARCH

Occupational exposure to soft paper dust and mortality

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ABSTRACT

Objectives Occupational exposure to soft paper dust is associated with impaired lung function. Whether there is an increased risk for asthma or chronic obstructive pulmonary disease (COPD) is unclear.

Methods We studied 7870 workers from three Swedish soft paper mills, and defined high-exposed workers, as having been exposed to soft paper dust exceeding 5 mg/m³ for at least 5 years. The remaining workers were classified as 'low exposed'. Person-years at risk were calculated and stratified according to gender, age and calendar-year. The follow-up time was from 1960 to 2013. The expected numbers of deaths were calculated using the Swedish population as reference and standardised mortality ratios (SMRs) with 95% CIs were assessed.

Results There was an increased mortality due to obstructive lung disease (asthma and COPD), among high-exposed workers, SMR 1.89, 95% CI 1.20 to 2.83, based on 23 observed cases. High-exposed workers had an increased mortality from asthma, SMR 4.13, 95% CI 1.78 to 8.14, based on eight observed cases. The increased asthma mortality was also observed among high-exposed men, SMR 4.38, 95% CI 1.42 to 10.2, based on five observed cases. The asthma mortality among low-exposed workers, both men and women, was not increased. The COPD mortality was not clearly increased among high-exposed workers (SMR 1.52, 95% CI 0.85 to 2.50).

Conclusion High occupational exposure to soft paper dust increases the mortality due to asthma, and the results suggest that soft paper dust levels in workplaces should be below 5 mg/m³.

INTRODUCTION

Worldwide, production of soft paper has grown by about one million tons per year in recent years, with mills in China producing approximately one-third of all papers in 2016.¹ In Sweden, the production of pulp and paper is an important trade, and one of the main products is soft paper. Soft paper is a semi-manufactured paper product predominantly made by recycled waste paper, but in many products a considerable amount of fresh pulp is also added.² Soft paper is then used for the production of toilet paper, paper towels and napkins. Soft paper production is a very dusty process, and levels of total dust above 5 mg/m³ were often found during 1980s in Swedish soft paper mills.³⁻⁴ However, during the last decades the dust levels have decreased considerably due to the introduction of exposure controls and process changes.⁵ Dust from soft paper mills

Key messages

What is already known about this subject?

- ▶ Occupational exposure to soft paper dust is associated with impaired lung function. Whether there is an increased risk for asthma or chronic obstructive pulmonary disease (COPD) is unclear.

What are the new findings?

- ▶ Occupational exposure to soft paper dust exceeding 5 mg/m³ for at least 5 years increases asthma mortality.

How might this impact on policy or clinical practice in the foreseeable future?

- ▶ The immediate implication is that the occupational exposure limit for paper dust should be below 5 mg/m³.

has been characterised and the main constituents are cellulose fibres and inorganic additives such as kaolin and talc.⁶ In Sweden, soft paper is produced in three large paper mills. The production is labour intensive and women represent a large proportion of the manual workers. The production process is different from other paper mills and historically the exposure levels to paper dust is considerably higher in soft paper mills compared with other paper mills producing printing paper.²

Occupational exposure to dust is associated with an increased risk for chronic obstructive pulmonary disease (COPD) and asthma.⁷ However, whether exposure to paper dust, especially soft paper dust, increases the risk for asthma and COPD is unclear. We have previously described a twofold (though not statistically significant) increased incidence rate of asthma, in a retrospective questionnaire study from one of the largest soft paper mills in Sweden.⁸ Further, we found in a case-control study an increased mortality from obstructive lung disease among workers in another large soft paper mill.⁹ Hence, there are indications of an increased mortality risk for obstructive lung disease among workers exposed to paper dust, but there is a lack of prospective, longitudinal studies in this field. In addition, there are cross-sectional studies indicating that heavily exposed workers have impaired pulmonary function, but dust levels below 5 mg/m³ seem not to impair lung function.^{3-5 10-12}

In this paper, we present all-cause and cause-specific mortality in a large cohort of workers from all three Swedish soft paper mills. A specific



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Table 1 Characteristics of the three included soft paper mills and number of included workers

Mill	Start of soft paper production	Inclusion period	Included women			Included men		
			N	Person-years	Deceased	N	Person-years	Deceased
A	1940	1960–2008	1 315	49 648	351	2 054	72 027	703
B	1943	1960–2008	1 048	38 106	236	2 042	77 926	866
C	1947	1960–2008	764	28 052	176	647	22 955	204
Total	NA	NA	3 127	115 805	763	4743	172 908	1 773

NA, not applicable.

aim was to study whether the mortality from obstructive lung diseases, asthma and COPD, was increased in relation to exposure to soft paper dust.

MATERIALS AND METHODS

Study population

This cohort comprises workers from three soft paper mills in Sweden. The characteristics of the cohort and the mills and the number of included workers and deceased workers, stratified for gender, are presented in [table 1](#). In Sweden, soft paper production started at mill A in 1940. A few years later mill B started on a small scale, but the production of soft paper increased considerably in 1960 in both mills. Both mills previously produced other kinds of paper and also sulfite pulp; this production ended in 1967. In third mill, mill C, the soft paper production started in 1947. Mill C was not included in our previous studies.

We had access to the personnel files from all three mills, and all workers employed for at least 1 year between 1960 and 2008 were included in the cohort. We extracted the personal data for each cohort member from the files, including the unique personal identification number and employment history (period of employment, department and occupation) at the mill. A total of 8624 workers were available, of which 271 were excluded due to incomplete personal identification number or lack of employment data. Workers who worked solely in the office (n=483) were excluded, resulting in a final cohort of 7870 workers potentially exposed to soft paper dust, of which 3127 were women.

Outcome definitions and follow-up

The start of the follow-up for this mortality study was 1960, or later, if the first employment was after 1960. The cohort was followed until death or until 2013, whichever came first. We calculated employment time as start of employment to end of last employment or end of cohort period. The cohort was matched with the Swedish Cause of Death Register. The period covered the seventh, eighth, ninth and tenth revisions of the International Classification of Diseases (ICD), and the codes used are summarised in [table 2](#).

Exposure assessments

In all mills area and personal sampling of total dust was conducted starting in the early 1970s. We have previously shown that total dust in soft paper mills can be used as a proxy for soft paper dust.⁶ We obtained historical stationary (n=532) and personal (n=415) measurements of total dust from the mills along with historical information about the work and the different departments at the mills. In addition, our research team has made 611 personal measurements at the mills over the time. We then assigned each department a mill-year and calendar-year specific level of soft paper dust from 1960 until 2008, allowing us to assess exposure to soft paper dust for every year for each worker with an

estimated mean level of dust (mg/m³). The exposure assessments have been described in more detail in a recent publication.¹³ Due to variations in exposure across time and duties, most workers were classified into more than one exposure category over the study period. The exposure assessments are presented in [table 3](#). Based on these results we defined ‘high-exposed’ workers, as those having been exposed to soft paper dust exceeding 5 mg/m³ for at least 5 years. The remaining workers were classified as ‘low exposed’.

Statistical analysis

The person-years at risk were calculated and stratified according to gender, age (5 year bins) and 1-year calendar periods. The first year of employment was not counted and for high-exposed workers, the first 5 years were counted as low-exposed years. The expected numbers of deaths were calculated using the Swedish population as the reference. Standardised mortality ratios (SMRs) were assessed and 95% CIs were outlined. The risks assessed as SMR were calculated for high-exposed workers and low-exposed workers, and stratified for gender. The analyses were performed using STATA SE V.14 (Stata Statistical Software, Release 14) and SAS V.9.4 (SAS Institute, Cary, North C, USA).

RESULTS

The cohort consisted of 7870 workers, and of these 2536 (32.2 %) died during the observation period, 1960–2013 ([table 1](#)). The total number of person-years of follow-up was 288 713, of which women comprised 115 805 (40.1 %) person-years. The high-exposed group included 478 (15.3%) of 3127 women, and

Table 2 Diagnostic codes used in the classification of causes of death

Causes of death	ICD			
	ICD-7	ICD-8	ICD-9	ICD-10
	1960–1968	1969–1986	1987–1996	From 1997 onwards
All malignancies	140–205	140–209	140–208	C00–C97
Lung, bronchus and pleura	162–163	162	162	C33–C34
Cerebrovascular disease	330–334	430–438	430–438	I60–I69
Ischaemic heart disease	420 to 422.1	410–414	410–414	I20–I25
Obstructive lung disease	501, 502, 527.1, 241	490–493	490–493	J40–J46
COPD	501, 502, 527.1	491 to 492	491 to 492	J43, J44
Asthma	241	493	493	J45–J46
All external causes	800–999	800–999	E800–999	V01–Y89

COPD, chronic obstructive pulmonary disease; ICD, International Classification of Diseases.

Table 3 Characteristics of workers and their years of exposure in different mean exposure levels of soft paper dust among included workers divided on high-exposed and low-exposed women and men

	High exposed to dust ≥ 5 years >5 mg/ m ³		Low exposed to paper dust		Total cohort
	Women	Men	Women	Men	
Included workers, N	478	648	2649	4095	7870
Age at hire, mean (SD)	30 (12)	28 (12)	27 (11)	27 (12)	27 (12)
Employment time, mean (SD)	18 (10)	23 (13)	8 (8)	13 (13)	12 (12)
Follow-up person-years, sum	19 516	26 800	96 289	146 107	288 713
Ever exposed to >5 mg/m ³ , N	478	648	609	703	2438
Years >5 mg/m ³ , mean (SD)	11.5 (6.3)	15.3 (11.6)	2.3 (1.2)	2.2 (1.2)	7.5 (8.5)
Cumulative dust exposure mg/m ³ years, mean (SD)	116 (75)	149 (117)	19 (20)	16 (23)	34 (60)
Numbers of workers (N) and years (mean) exposed to different levels of total dust					
Exposed to mean 0.01 mg/m ³ , N	8	13	60	86	167
Years 0.01 mg/m ³ , mean (SD)	5.4 (5.5)	7.2 (5.8)	9.3 (9.7)	11.9 (9.9)	10.3 (9.5)
Exposed to mean 0.1 mg/m ³ , N	9	50	191	918	1168
Years 0.1 mg/m ³ , mean (SD)	3.6 (6.4)	9.8 (7.5)	6.6 (8.1)	12.7 (13)	11.5 (12)
Exposed to mean 0.5 mg/m ³ , N	37	120	249	1671	2077
Years 0.5 mg/m ³ , mean (SD)	8.6 (7.3)	10.1 (10)	6.7 (6.7)	11.9 (13)	11.1 (12)
Exposed to mean 1.5 mg/m ³ , N	212	205	920	1094	2431
Years 1.5 mg/m ³ , mean (SD)	9.8 (7.8)	8.5 (7.5)	7.3 (6.9)	7.7 (7.7)	7.8 (7.4)
Exposed to mean 3 mg/m ³ , N	251	252	1406	1206	3115
Years 3 mg/m ³ , mean (SD)	5.3 (2.8)	6.8 (5.7)	6.4 (6.7)	8.2 (11)	7.0 (8.3)
Exposed to mean 7 mg/m ³ , N	427	584	500	619	2130
Years 7 mg/m ³ , mean (SD)	9.9 (5.5)	13.1 (10)	2.2 (1.2)	2.2 (1.2)	6.7 (7.6)
Exposed to mean 15 mg/m ³ , N	166	189	195	114	664
Years 15 mg/m ³ , mean (SD)	7.5 (7.2)	12.0 (11)	1.8 (1.0)	2.0 (1.2)	6.2 (8.1)

Every worker can be exposed to several different exposure levels during their employment. Mean cumulative dust exposure is also given. SD, standard deviation.

648 (13.7%) of the 4 743 men. In general, the paper dust levels in the 1970s to 1980s were between 5 and 10 mg/m³, but higher levels also existed; 8.4% of the workers were exposed to levels exceeding 10 mg/m³.

The all-cause mortality was similar to the Swedish population, both among the high-exposed and low-exposed workers (table 4). The cause-specific mortalities from malignancies in the bronchus, lung and pleura, cerebrovascular disease, ischaemic heart disease and all external causes were similar to the Swedish population, in the whole cohort, as well as among men and women (table 4).

There was an increased mortality due to obstructive lung disease, defined as COPD and asthma, among high-exposed workers, SMR 1.89, 95% CI 1.20 to 2.83, based on 23 observed cases (table 4). The estimates were also increased among high-exposed women, SMR 2.15, 95% CI 0.98 to 4.08 as well as among high-exposed men, SMR 1.75, 95% CI 0.96 to 2.94. When separating between asthma and COPD, the increased mortality was found in relation to asthma. High-exposed workers had an increased mortality from asthma, SMR 4.13, 95% CI 1.78 to 8.14, based on eight observed cases. Increased asthma mortality was also observed among high-exposed men, SMR 4.38, 95% CI 1.42 to 10.2, based on five observed cases. High-exposed women also had an increased SMR 3.77, 95% CI 0.78 to 11.0; however, with a wide CI comprising unity and based on three observed cases. The asthma mortality among low-exposed workers, both men and women, was not increased. The COPD mortality was not clearly increased among the high-exposed workers overall (SMR 1.52, 95% CI 0.85 to 2.50) or among high-exposed men (SMR 1.36, 95% CI 0.62 to 2.58) or among high-exposed women (SMR 1.84, 95% CI 0.67 to 4.00).

Of the eight high-exposed workers who died from asthma, 50% (n=4) died before the age of 60 years. Of the seven low-exposed workers who died from asthma, 14% (n=1) died before the age of 60 years.

DISCUSSION

This large longitudinal cohort study of soft paper workers provides evidence that high exposure to soft paper dust, that is, over 5 mg/m³ for more than 5 years, is associated with increased asthma mortality, supporting and clarifying relationships observed in previous case-control and cross-sectional studies.

This is the only existing longitudinal cohort study of mortality among workers exposed to soft paper dust. An additional strength is that we have access to detailed measurements of soft paper dust exposure levels and a complete employment history, making it possible to assess the cumulative exposure for each worker. During the 1970s and 1980s the soft paper dust levels were between 5 and 10 mg/m³, but higher levels exceeding 10 mg/m³ also existed. During more recent years the exposure levels were reduced to around 1–2 mg/m³. Our findings in the present study indicate that working for at least 5 years at dust levels exceeding 5 mg/m³ is associated with significant increased asthma mortality, which was not observed among the low-exposed workers with a similar duration of exposure. We chose 5 mg/m³ as the threshold, as previously this level was the Swedish threshold limit value used for paper dust. In addition, impaired lung function due to paper dust exposure seems not to occur at levels below 5 mg/m³.⁵ Five years duration was an ad hoc decision.

Previous studies from other parts of the pulp and paper industry mostly comprise pulp and paper mill workers, and these

Table 4 Mortality among Swedish soft paper mill workers 1960–2013

Causes of death	All n=7870				Women n=3127				Men n=4743			
	High		Low		High		Low		High		Low	
	O*	SMR (95% CI)	O*	SMR (95% CI)	O*	SMR (95% CI)	O*	SMR (95% CI)	O*	SMR (95% CI)	O*	SMR (95% CI)
All causes	551	1.08 (0.99 to 1.17)	1985	0.99 (0.95 to 1.04)	208	1.12 (0.97 to 1.28)	555	0.97 (0.89 to 1.06)	343	1.05 (0.94 to 1.17)	1430	1.00 (0.95 to 1.05)
All malignancies	147	1.15 (0.98 to 1.36)	459	0.88 (0.80 to 0.96)	62	1.29 (0.99 to 1.65)	152	0.88 (0.75 to 1.04)	85	1.07 (0.86 to 1.33)	307	0.88 (0.78 to 0.98)
Lung, bronchus and pleura malignancies	24	1.23 (0.79 to 1.83)	80	0.94 (0.74 to 1.17)	5	0.89 (0.29 to 2.09)	29	1.26 (0.84 to 1.81)	19	1.37 (0.82 to 2.13)	51	0.82 (0.61 to 1.08)
Cerebrovascular disease	62	1.30 (1.00 to 1.67)	158	0.95 (0.81 to 1.11)	29	1.39 (0.93 to 2.00)	37	0.68 (0.48 to 0.93)	33	1.24 (0.85 to 1.74)	121	1.08 (0.90 to 1.29)
Ischaemic heart disease	141	1.06 (0.90 to 1.26)	533	1.08 (0.99 to 1.17)	38	0.98 (0.69 to 1.35)	105	1.11 (0.91 to 1.34)	103	1.10 (0.90 to 1.33)	428	1.07 (0.97 to 1.18)
Obstructive lung disease	23	1.89 (1.20 to 2.83)	47	0.96 (0.71 to 1.28)	9	2.15 (0.98 to 4.08)	22	1.43 (0.89 to 2.16)	14	1.75 (0.96 to 2.94)	25	0.75 (0.48 to 1.10)
COPD	15	1.52 (0.85 to 2.50)	38	0.94 (0.67 to 1.29)	6	1.84 (0.67 to 4.00)	19	1.50 (0.90 to 2.34)	9	1.36 (0.62 to 2.58)	19	0.69 (0.41 to 1.08)
Asthma	8	4.13 (1.78 to 8.14)	7	0.95 (0.38 to 1.96)	3	3.77 (0.78 to 11.0)	3	1.25 (0.26 to 3.66)	5	4.38 (1.42 to 10.2)	4	0.81 (0.22 to 2.07)
All external causes	34	1.15 (0.79 to 1.60)	173	1.15 (0.98 to 1.33)	6	0.78 (0.29 to 1.70)	38	1.18 (0.83 to 1.61)	28	1.27 (0.85 to 1.84)	135	1.14 (0.95 to 1.34)

Data represent SMRs with 95% CI.

*Number of observed cases.

COPD, chronic obstructive pulmonary disease; SMRs, standard mortality ratios.

groups have quite different exposures. From such studies it is difficult to conclude about the effects from paper dust. In some studies, not comprising soft paper mills, paper dust exposure from production of printing paper have been investigated.^{14 15} The dust levels were below 3 mg/m³, and there was no increased risk of asthma.^{14 15} An additional confounder linked to the production of printing paper is that workers often are exposed to bleaching agents such as previously chlorine, and currently ozone and hydrogen peroxides.¹⁶

Exposure to dust is increasingly associated with asthma and COPD.⁷ The present study is the first study that links exposure to soft paper dust with increased asthma mortality. Previous studies have described increased mortality due to obstructive lung disease as well as an insignificantly increased incidence rate of asthma,^{8 9} but conflicting data exist.^{2 17} A suspected case of occupational asthma due to paper dust (specifically cellulose dust) has recently been described.¹⁸

The results are also consistent with previous studies showing that high occupational exposure (>5 mg/m³) to soft paper dust is associated with impaired lung function, mainly decreased forced expiratory volume in onesecond and forced vital capacity.^{3–5 12} However, in two studies with lower exposure levels (≤5 mg/m³), there was no association between exposure to soft paper dust and lung function impairment.^{10 11}

Increased asthma mortality has previously been linked to occupational exposure to dust, such as wood dust, farming dust and dust in the food industry.^{19–22} Increased asthma mortality associated with certain exposures, such as soft paper dust or other exposures with irritating properties, may reflect that the exposure has triggered fatal asthma attacks leading to death, without being the underlying cause of the disease, that is, causing severe asthma exacerbations.²³ We do not have information available whether the cases in the present study were triggered by attacks at workplace leading to death, but 50% of the high-exposed asthma cases died before the age of 60, compared with 14% of the low-exposed cases. Still, these results underscore the importance of keeping the exposure to dust and other irritants low.

Exposure to organic dust has been associated with impaired lung function, and exposure to organic dust has been associated with an increased incidence of COPD.^{24 25} We consider soft paper dust to represent a variety of organic dusts, even if it has inorganic constituents. However, the results from the current study are inconclusive regarding the risk of COPD in relation to exposure to soft paper dust.

The study has a number of limitations. There may be misclassification between asthma and COPD. In the period when ICD-8 was used there was a rule that COPD should be given priority as the underlying cause, if COPD and asthma were mentioned together on the death certificate.²⁶ This rule was removed in the later ICD versions, and according to a British study the potential misclassification seems to have been important.²⁷ There is a possibility that workers with severe asthma could have been classified also as having COPD, which would result in an underestimation of the true asthma risk. However, we consider this misclassification of minor importance, and restricted to a short period of time.

Another weakness is the Healthy Worker Survivor Effect.²⁸ Due to the dusty and demanding work in paper mills, less healthy workers will terminate their employment or be transferred to less dusty positions in the mills. It is also likely that the Healthy Worker Survivor Effect will be quite substantial, as high exposure is defined as more than 5 mg/m³ for at least 5 years. This will probably result in weakening of the associations between soft paper dust exposure and outcomes. This is likely

further accentuated by our use of the total Swedish population as the comparison group, rather than the occupationally active part of the population.

Another limitation is the lack of information on smoking habits for the entire cohort. In one of the mills, we have information about smoking habits, and high-exposed workers were more often current smokers as compared with low-exposed workers (30% vs 22%).⁵ Asthma (and COPD) is associated with smoking, so confounding due to smoking is present.^{19 29}

The strengths of the present study are several. The prospective design with a cohort inclusion based on the personal files in the mills means that the cohort comprises almost all workers who have been employed in these mills, giving us a comprehensive perspective of employment and exposures at the mills. Furthermore, due to our use of personal identification numbers, our medical follow-up has a very high degree of completeness.

Our results provide further evidence that high exposure to soft paper dust increases the mortality due to asthma. The results suggest that dust levels in workplaces should at least be below 5 mg/m³.

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Disclaimer The lead author (KT) affirms that the manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Competing interests None declared.

Patient consent for publication Not required.

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Data availability statement Data are available upon reasonable request. The data are available by the author. But an access needs a permission from a Swedish Committee of Ethics.

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