

# Cardiovascular mortality among pulp mill workers

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## Abstract

**A mortality study, concentrating on cardiovascular mortality, was undertaken among Finnish sulphite mill workers exposed to sulphur dioxide and sulphate mill workers exposed to hydrogen sulphide and organic sulphides. They had been employed continuously for at least one year between 1945 and 1961. National death rates were used for comparison and mortality was followed up until 31 December 1981. Among the cohort exposed to sulphur dioxide (2268 person-years), an excess of cardiovascular deaths was noticed among the men (24 obs, 19.4 exp, SMR 123) due to an excess of coronary deaths (18 obs, 12.4 exp, SMR 145). The cardiovascular mortality was not affected by the duration of occupational exposure or follow up period in this cohort. Among the men exposed to hydrogen sulphide and organic sulphides (4179 person-years), there was also an excess of cardiovascular deaths (37 obs, 24.7 exp, SMR 150) due to an excess of coronary deaths (25 obs, 16.7 exp, SMR 150). These excesses increased with longer follow up period. As common risk factors of coronary heart disease could not explain the findings in the sulphate mill cohort, they may be associated with exposure to hydrogen sulphide and organic sulphides.**

Few studies have been published on the mortality of pulp workers and of these, some have found an increased mortality from cardiovascular diseases<sup>1,2</sup> but others have not.<sup>3,4</sup>

Milham and Demers conducted a proportionate mortality study using the death records of 2113 United States and Canadian members of the Pulp, Sulphite and Paper Workers' Union and found an excess of deaths due to circulatory diseases (1110 obs, 975.2 exp, PMR 114).<sup>1</sup> Recently, the mortality among workers in the Finnish pulp and paper industry was evaluated in a retrospective cohort study of 3520 workers.<sup>2</sup> There was an excess number

of deaths from diseases of the circulatory system among the men ( $n = 2696$ ) in the whole cohort (489 obs, 404.9 exp, SMR 121, 95% CI 109-134) due to an excess of deaths from ischaemic heart disease (332 obs, 259.5 exp, SMR 128, 95% CI 114-144). The excess of coronary deaths was found among the men in the sulphite mill, sulphate mill, paper mill, maintenance department, and power plant subcohorts. The excess mortality from cardiovascular diseases and especially from ischaemic heart disease could not be attributed to differences in smoking habits.

Workers in pulp mills are exposed mainly to gaseous sulphur compounds. In the power plant departments of sulphate pulp mills, including evaporation plants and recovery boilers, the exposure to sulphur compounds may be particularly high.<sup>5</sup> Although the possible role of sulphur compounds other than carbon disulphide in the pathogenesis of coronary heart disease has not been established, it is known that at least hydrogen sulphide in high concentrations affects the heart rate and causes changes in the ECG.<sup>6</sup> Interestingly, the most significant excess mortality from ischaemic heart disease in the Finnish cohort study<sup>2</sup> was observed among the male power plant workers, who had had the highest exposure to gaseous sulphur compounds.

To evaluate the possible effects of sulphur dioxide, emerging from the sulphite process, as well as hydrogen sulphide and organic sulphides emerging from the sulphate process on cardiovascular mortality of pulp workers the data of the previous study<sup>2</sup> was further analysed. It was also analysed to see whether exposure to sulphur compounds was associated with mortality caused by diseases of blood and blood forming organs or by diseases of the respiratory system.

## Material and methods

The basic material consisted of the workers at three pulp and paper mills owned by the same company in the province of Kymi in south eastern Finland. Two mills used the alkaline or sulphate pulping process and were still in operation. The third mill, in operation from 1910 to 1962, had used the acidic or sulphite pulping process.

All workers who had been employed continuously for at least one year between 1 January 1945 and 31 December 1961 were included in the study. The basic source of the data was the company employment files, where all changes of job or

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foremen for each of the approximately 50 000 subjects ever employed were recorded.

One cohort was formed of male workers who had had a higher than average exposure to sulphur dioxide within the sulphite mill. These were workers in the digesting, screening, washing, evaporation, and acid preparation departments. Another cohort was formed of male workers who had had a higher than average exposure to hydrogen sulphide and organic sulphides within the sulphate mills. They worked in the digesting, washing, evaporation, and cooking liquor preparation departments.

The personal data were confirmed from the National Population Register and, when necessary, from local population registers. The cause of death was retrieved through the Central Statistical Office. Information was also obtained from Sweden and from the authorities in Norway, Denmark, Canada, and Australia.

The person-years were calculated until death or the closing date of the study (31 December 1981). The expected numbers of deaths, calculated by five year age groups and five year calendar periods, were calculated for deaths from all causes (8th revision of the International Classification of Diseases,<sup>7</sup> ICD 000-999) from diseases of blood and blood forming organs (ICD 280-289), diseases of the circulatory system (ICD 390-458), ischaemic heart disease (ICD 410-414), and from diseases of the respiratory system (ICD 460-519). The general Finnish population was used for reference.

The age, sex, and calendar period specific numbers of person-years at risk in the cohorts were multiplied by the corresponding death rates. Standardised mortality ratios were obtained as the ratios of the observed to the expected numbers of cases. The Poisson distribution was used when testing for the statistical significance of the differences between the observed and expected numbers of deaths and when calculating the 95% confidence intervals for SMRs.

Based on the follow up separate analyses were accomplished of those with a follow up time of five years or less, six to 15 years, and more than 15 years. Furthermore, there were separate analyses for two categories according to the duration of employment (one to four years and five years or more).

## Results

### WORKERS EXPOSED TO SULPHUR DIOXIDE

In the cohort exposed to sulphur dioxide (2268 person-years) there was an increased overall mortality among the men (44 obs, 39.1 exp, SMR 112, 95% CI 82-151) (table 1). There were eight observed deaths versus 6.5 expected among the men with a follow up period of six to 15 years (SMR 124, 95% CI 53-244) and 33 observed deaths versus 30.3 expected among the men with a follow up period of more than 15 years (SMR 109, 95% CI 75-153).

An excess of cardiovascular deaths was noticed among the men (24 obs, 19.4 exp, SMR 123, 95% CI 79-184) (table 1). There were six observed deaths from cardiovascular diseases versus 2.7 expected among the men with a follow up period of six to 15 years (SMR 221, 95% CI 81-480), and 17 observed cases versus 16.0 among the men with a follow up period of more than 15 years (SMR 106, 95% CI 62-170).

The excess of cardiovascular deaths among the men was due to an excess of coronary deaths (18 obs, 12.4 exp, SMR 145, 95% CI 86-229) (table 1). Four deaths were from ischaemic heart disease versus 1.8 expected (SMR 223, 95% CI 61-572) among the men with a follow up period of six to 15 years and 14 observed deaths versus 10.4 expected (SMR 135, 95% CI 74-227) among the men with a follow up period of more than 15 years.

The observed number of deaths from all causes did not differ from that expected among the men in the cohort exposed to sulphur dioxide with an occupational exposure of five years or more (1336 person-years) but there was a slight excess of cardiovascular deaths (17 obs, 15.2 exp, SMR 112, 95% CI 65-179) and an excess of coronary deaths (13 obs, 9.5 exp, SMR 136, 95% CI 73-233) (table 1). The follow up period did not notably affect the cardiovascular or coronary mortality in this group.

In the cohort exposed to sulphur dioxide there was one death from diseases of blood and blood forming organs versus 0.1 expected. He had had an occupational exposure of more than five years. There was an excess of deaths from respiratory diseases among the men exposed to sulphur dioxide (6 obs, 2.6 exp, SMR 230, 95% CI 84-500), all these deaths

Table 1 Observed and expected numbers of deaths from all causes and from diseases of the circulatory system and the corresponding SM with 95% CI by duration of employment, referred to the population of Finland, in men exposed to sulphur dioxide

Cause of death (ICD, 8th rev)	Duration of employment (y)											
	1-4				≥5				Total			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95%
All causes (000-999)	15	9.3	162	91-267	29	29.9	97	65-139	44	39.1	112	82-151
Diseases of the circulatory system(390-458):	7	4.3	164	66-339	17	15.2	112	65-179	24	19.4	123	79-179
Ischaemic heart disease (410-414)	5	2.9	172	56-402	13	9.5	136	73-233	18	12.4	145	86-227

Table 2 Observed and expected numbers of deaths from all causes and from diseases of the circulatory system and the corresponding SMRs with 95% CI by duration of employment, referred to the population of Finland, in men exposed to hydrogen sulphide and organic sulphides

Cause of death (ICD, 8th rev)	Duration of employment (y)								Total			
	1-4				≥5							
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
causes (000-999)	16	9.6	167	95-271	39	41.8	93	66-128	55	51.4	107	81-139
diseases of the circulatory system (390-458):	9	4.2	216	99-410	28	20.5	136	91-197	37	24.7	150	105-206
Ischaemic heart disease (410-414)	7	2.8	254	102-523	18	13.9	129	77-205	25	16.7	150	97-222

occurring among the men with an occupational exposure of one to four years.

#### WORKERS EXPOSED TO HYDROGEN SULPHIDE AND ORGANIC SULPHIDES

In the sulphate mill cohort exposed to hydrogen sulphide and organic sulphides (4179 person-years for the men) the overall mortality was slightly increased (55 obs, 51.4 exp, SMR 107, 95% CI 81-139) (table 2). There were 38 deaths versus 29.3 expected (SMR 130, 95% CI 92-178) among the men of this cohort with a follow up period of more than 15 years.

The increased overall mortality among the men was due to excesses of cardiovascular deaths (37 obs, 24.7 exp, SMR 150, 95% CI 105-206) and especially of coronary deaths (25 obs, 16.7 exp, SMR 150, 95% CI 97-222) (table 2). There were two observed cardiovascular deaths (both due to ischaemic heart disease) versus 2.4 expected among the men of this cohort with a follow up period of up to five years, seven observed deaths versus 7.1 expected among those with a follow up period of six to 15 years, and 28 observed deaths versus 15.22 expected (SMR 184, 95% CI 122-266) among those with a follow up period of more than 15 years. There were four observed coronary deaths versus 4.7 expected among the men with a follow up period of six to 15 years and 19 observed deaths versus 10.5 expected (SMR 182, 95% CI 109-284) among those with a follow up period of more than 15 years.

Among the men of the sulphate mill cohort with an occupational exposure of more than five years (2932

person-years), the overall mortality was slightly lower than expected (39 obs, 41.8 exp, SMR 93, 95% CI 66-128) (table 2). Nevertheless, among the men of this exposure category with a follow up period of more than 15 years there were 30 observed deaths versus 24.2 expected (SMR 124, 95% CI 84-177) (table 3).

The cardiovascular mortality was increased among men who had been exposed for more than five years (28 obs, 20.5 exp, SMR 136, 95% CI 91-197) due to an excess of coronary deaths (18 obs, 13.9 exp, SMR 129, 95% CI 77-205) (table 2). In this exposure category there were 22 observed cardiovascular deaths versus 12.7 expected among the men with a follow up period of more than 15 years (SMR 173, 95% CI 109-262) and 14 observed coronary deaths versus 8.7 expected (SMR 162, 95% CI 88-272) (table 3).

Among the men exposed to hydrogen sulphide and organic sulphides, there were no deaths due to diseases of blood and blood forming organs. One death was due to respiratory diseases versus 3.0 expected.

#### Discussion

Because of the healthy worker effect, mortality among industrial cohorts is usually below the expected level. The increased overall mortality in the whole cohort of Finnish pulp and paper workers could be largely attributed to the excess of deaths from diseases of the circulatory system, and especially from ischaemic heart disease. Differences in smoking habits did not explain the findings, although the proportion of smokers among the men of the sulphate mill subcohort was higher (80%) than in the other subcohorts. On the basis of the previous findings, the interest of the present study was focused mainly on cardiovascular diseases and especially on ischaemic heart disease.

In general, there was an excess risk of cardiovascular death among both the workers exposed to sulphur dioxide and those exposed to hydrogen sulphide and organic sulphides. This excess was small and in most subgroups statistically non-significant. Nevertheless, the trend was consistent with a real association between the exposure at issue and mortality.

Table 3 Observed and expected numbers of deaths from all causes and from diseases of the circulatory system and the corresponding SMRs with 95% CI referred to the population of Finland in men exposed to hydrogen sulphide and organic sulphides for more than five years and followed up for more than 15 years

Cause of death (ICD, 8th revision)	Obs	Exp	SMR	95% CI
All causes (000-999)	30	24.2	124	84-177
Diseases of the circulatory system (390-458):	22	12.7	173	109-262
Ischaemic heart disease (410-414)	14	8.7	162	88-272

In the cohort exposed to sulphur dioxide the duration of employment had only a minor effect on the cardiovascular and coronary mortality. In relation to the follow up period, there were excesses of deaths from these diseases among the men with a follow up of six to 15 years but the numbers of the observed and expected deaths were rather low. Furthermore, the excesses in cardiovascular and coronary deaths in this cohort were of the same magnitude as in the original pulp and paper cohort as a whole.<sup>2</sup> Therefore, in the case of exposure to sulphur dioxide it is difficult to establish any clear aetiological connection with the increased cardiovascular and coronary mortality.

In the sulphate mill cohort of the present study, exposed to hydrogen sulphide and organic sulphides, the excesses of circulatory and coronary deaths increased with follow up period. On the other hand, the excesses of these deaths were slightly more pronounced among the men with an occupational exposure of one to four years. Probably workers with cardiovascular symptoms tend to move to departments without exposure to gaseous sulphur compounds, so that the workers with a longer occupational exposure appear to be healthier; however, the magnitude of this effect cannot be estimated. It should be noted that the excess of cardiovascular and coronary deaths also increased with increasing follow up period among the men with an occupational exposure of at least five years.

Hydrogen sulphide is known to have cardiovascular effects.<sup>6</sup> The effects of organic sulphides have not been studied in this respect but their effect on cellular respiration is analogous with that of hydrogen sulphide.<sup>8</sup> The possible role of gaseous sulphur compounds, especially hydrogen sulphide, in the pathogenesis of coronary heart disease, however, has still not been established.

As the proportion of smokers among the men in the sulphate mill subcohort of the basic study population<sup>2</sup> was higher (80%) than in the other subcohorts,<sup>9</sup> and also higher than the prevalence of smoking among Finnish men reported by, for example, Karvonen *et al*<sup>10</sup> and Poukkula *et al*,<sup>11</sup> smoking has certainly a role as a confounder. It is unlikely, however, that the excess cardiovascular mortality among the men exposed to hydrogen sulphide and organic sulphides could have been caused solely by differing smoking habits.

There have been regional differences in cardiovascular mortality in Finland, with the highest mortality rates in the eastern and the lowest in the south western part of the country. In the province of Kymi the coronary mortality has been somewhat higher than in the western part of the country but considerably lower than in north Carelia, with high coronary death rates.<sup>12-14</sup> As there were no excesses of deaths from cardiovascular diseases or ischaemic heart disease among the male sawmill workers, forming a comparison group in the basic study<sup>2</sup> and also originating from the province of Kymi, it could be

assumed that regional differences in mortality could not explain the findings of the present study.

There was not much information available on the serum cholesterol or blood pressure levels of the study population, other than in the records kept in occupational health departments. It is unlikely that workers with high serum cholesterol or blood pressure would have been overrepresented in the cohort as compared with the general population. Moreover, one would expect that the organised occupational health services could have had an effect of lowering both serum cholesterol and blood pressure levels among the workers.

As the common risk factors of coronary heart disease cannot explain the findings of this study, it may be assumed that exposure to hydrogen sulphide and simple organic sulphides—for example, methyl mercaptan—at the workplaces may be connected with increases in cardiovascular and coronary mortality. To establish the exact nature of this relation, more extensive studies are necessary.

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