

Literature review of epidemiological studies on the health effects on workers in elemental chlorine free pulp mills and totally chlorine free pulp mills

Prepared for the Tasmanian Resource Planning and Development Commission

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BACKGROUND OF THE AUTHOR

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EXECUTIVE SUMMARY

Background

The project is a literature-based review of epidemiological studies on the health effects on workers in elemental chlorine free (ECF) pulp mills and totally chlorine free (TCF) pulp mills. Its overall aim was to provide a brief but thorough and critical review of published information on the occupational health and safety of pulp mill workers, with primary emphasis on whether there is evidence of different health effects on workers involved in ECF or TCF processes.

Methods

Nearly all the studies were of ECF mills, and there were no studies comparing the health and safety of workers in ECF mills to workers in TCF mills. Therefore, direct comparison between the mill types was not possible. Instead, exposures common to the two mill types, and exposures specific to one mill type, were identified. Health effects related to these exposures were identified where possible.

Exposures

A wide variety of common exposures occur in both ECF and TCF pulp mills. The main difference in exposures between the two plants is the use of chlorine dioxide in ECF plants, leading to potential exposure to chlorine dioxide, chlorine and organochlorines. In TCF plants, there is higher potential exposure to ozone, but no exposure to chlorine dioxide or chlorine, and little likelihood of exposure to organochlorines.

Findings

Compared with the general population, pulp and paper mill workers have been found to have a lower total mortality from all causes and from all cancers.

Chlorine, chlorine dioxide and ozone are all potent respiratory irritants. All have been associated with respiratory symptoms of irritation, asthma-like symptoms, diagnosed asthma and worsening respiratory function. There is good evidence that work in ECF and TCF mills increases the risk of having respiratory symptoms such as cough and wheeze, decreases lung function, and increases the risk of reporting symptoms consistent with asthma or with having been diagnosed with adult-onset asthma. No significant differences should be expected in the level of respiratory symptoms or disorders in workers from ECF mills compared to TCF mills, provided that the level and extent of leaks is similar.

Work in pulp mills entails exposure to many substances that have been identified as definite or probable carcinogens. Research shows that pulp mill workers are probably at increased risk of developing lung cancer and mesothelioma, and this increased risk probably arises due to exposure to asbestos. This is not likely to be related to the mill process (i.e. to be greater in ECF or TCF mills). Stomach cancer is the only other cancer consistently associated with pulp mill work. Much of this increased risk may be related to confounding from diet*. Pulp mill work has also been associated with increased risk of many other cancer types, but the evidence for them is inconsistent, and at least some of the associations are probably due to confounding.

The one area of difference between ECF mills and TCF mills that may lead to differing cancer risks relates to "organochlorines". These by-products are produced during the chemical stage of pulping in ECF mills, but do not occur in significant quantities in TCF processes. Organochlorines (mainly dioxins) have been associated with a wide range of health effects. If considerable exposure occurred in ECF mills to organic chlorinated compounds, then workers at those plants could be expected to have an increased risk of developing some cancers, particularly soft tissue sarcoma and non-Hodgkin's lymphoma, compared with workers at TCF mills. However, such exposure is not likely in modern mills.

Conclusions

In summary, it is likely that there are no major differences in non-malignant respiratory disorders between ECF and TCF mills, since chlorine, chlorine dioxide and ozone are all potent respiratory irritants. If considerable exposure occurred in ECF mills to organic chlorinated compounds, then workers at those plants could be expected to have an increased risk of developing some cancers, particularly soft tissue sarcoma and non-Hodgkin's lymphoma, compared with workers at TCF mills. However, such exposure is not likely in modern mills.

* Confounding describes the situation where an apparent association between an exposure and a disease is actually due to the presence of another exposure. A common example is a chemical apparently causing an increased risk of lung cancer in a group of workers, but the increased risk really being due to the fact that a lot of the workers smoke.

1. INTRODUCTION

1.1 BACKGROUND

The Tasmanian Resource Planning and Development Commission has been requested by the Tasmanian Government to develop environmental guidelines for any new bleached eucalypt kraft pulp mill in Tasmania.

One issue brought to the attention of the Commission is the health of workers in ECF pulp mills and TCF pulp mills. This project is designed to address that issue.

1.2 PROJECT AIMS

The project is a literature-based review of epidemiological studies on the health effects on workers in elemental chlorine free (ECF) pulp mills and totally chlorine free (TCF) pulp mills. Its overall aim is to provide a brief but thorough and critical review of published information on the occupational health and safety of pulp mill workers, with primary emphasis on whether there is evidence of different health effects on workers involved in ECF or TCF processes.

1.3 OUTLINE OF THE STRUCTURE OF THE REPORT

The report has six sections. After an introduction in Section 1, the methodology for the study is described in Section 2. Section 3 describes the main exposures in ECF and TCF pulp mills. The health effects are described in Section 4, followed in Section 5 by a specific consideration of how these health effects might differ between workers in ECF mills and that in TCF mills. Sections 3 and 4 begin with summaries of the main findings from the section. Section 6 presents a brief consideration of some of the methodological issues involved in preparing the report.

2. METHODS

2.1 INTRODUCTION

The information presented in this report is based on published, peer-reviewed literature. Other relevant information from on-line sources has been included where appropriate. No new investigations were undertaken to obtain information on exposure or risk.

2.2 IDENTIFYING RELEVANT LITERATURE

English language literature published up to early 2004 was searched for relevant articles. Key words used were:

“pulp”, “pulp mill”, “elemental chlorine free”, “totally chlorine free”

AND one or more of:

- “disease”, “disorder”, “condition”, “illness”;
- “cancer”, “carcinogen”, “malignant”, “malignancy”; and
- “asthma”, “chronic obstructive pulmonary disease”, “chronic obstructive lung disease”, “chronic airflow limitation”, “lung”, “respiratory”; “laryngeal”, “nasal”.

The main searches were conducted through Medline, but general Internet searches were also used. Secondary follow-up of sources cited in reference lists was also undertaken.

Reviewing literature

All articles identified through the literature search were considered for inclusion. Abstracts or the full text were read and assessed to determine the relevance of papers for the review. The full text of all major articles was read, but only the abstracts used for some less important studies. Papers that considered pulp mills, or pulp and paper mills together, were included. Papers that only considered paper mills, or only considered paper mill workers, were excluded. The methodology, results and conclusions for each paper were critically appraised prior to a final decision on inclusion.

The majority of studies were of good quality and considered workers from ECF pulp mills. Most of the studies that considered cancer were large cohort studies of between 10,000 and 30,000 subjects, with exposures that started somewhere between 1920 and 1960 and finished between 1980 and 1990. Mortality studies were similar, but the number of

subjects in most studies varied between about 1,000 and 60,000. The respiratory-focussed studies tended to be much smaller, with 100 to 300 subjects in each, and to cover more recent exposures, including those in the 1990s. This report does not include a summary of each paper, as this was considered beyond the scope of the work required by the Commission and not necessary to meet the needs of the Commission for this project.

2.3 ETHICAL ISSUES

No important ethical issues were relevant to the project, as all the information used was in the public domain.

2.4 APPROACH USED

Nearly all the studies were of ECF mills, and there were no studies comparing the health and safety of workers in ECF mills to workers in TCF mills. Therefore, direct comparison between the mill types was not possible. Instead, exposures common to the two mill types, and exposures specific to one mill type, were identified. Health effects related to these exposures were identified where possible. All other things being equal, those health effects arising from exposures common to both mill types can be expected to occur in workers in either mill type. Health effects arising only from an exposure specific to one mill type can be presumed to be specific to that mill type.

Unfortunately, several studies identified apparent health effects, but without being able to confidently identify the causative exposures. For these health effects, comment is made as to the likely causative exposures and therefore the likelihood that they would be relevant to workers at one or both mill types.

The approach taken was to summarise the main workplace exposures in each mill type and the literature on each of the main health effects studied in pulp mill workers. This information was then used to compare and contrast the likely health effects of work in ECF and TCF pulp mills.

3. EXPOSURES IN ECF AND TCF MILLS

3.1 THE HISTORY OF PULP MILLS

Pulp mills produce paper pulp from timber. Where bleached kraft pulp is produced, the process requires pulping of the raw timber, washing, and then some form of bleaching. Several different approaches to pulping have been used – chemical pulping, mechanical pulping and semi-chemical pulping – of which chemical pulping is the most common. This involves cooking wood chips in large pressure vessels. The kraft, or sulphate, process involves cooking the pulp in the presence of sodium hydroxide and sodium sulphide. The sulphite process instead uses bi-sulphite during cooking.

After washing, if white rather than brown pulp is being produced, the pulp undergoes some form of bleaching to remove the colour. Several approaches have been used – these have been briefly reviewed recently¹ - but the main two approaches involve the use of chlorine and the use of non-chlorine methods. Early chlorine-based mills used elemental chlorine, but during the 20th century many mills producing bleached pulp eliminated the use of elemental chlorine and replaced it with use of chlorine dioxide. These mills have become known as “Elemental Chlorine Free” (ECF) mills. A different processing approach based on ozone (used with peroxides and caustic soda) rather than chlorine or chlorine dioxide was developed in the 1950s and 1960s, and the first commercial plant went into service in Sweden in 1990. This approach does not use chlorine at all, and so is called “Totally Chlorine Free” (TCF). TCF mills have not become common and today account for only six per cent to seven per cent of bleached pulp production world-wide¹⁻⁴.

3.2 PULP AND PAPER MILLS

Pulp mills often operate in conjunction with paper mills. The mills may be next to each other, or essentially part of one facility. This means that workers at a pulp mills may be exposed to exposures associated with the paper mill, and vice versa.

3.3 MAIN EXPOSURES

A wide variety of exposures occur in both ECF and TCF pulp mills.

A large, multi center study of ECF mills and any attached processing departments found that the most frequently identified specific exposures in production areas of pulp mills were sulphur dioxide and chlorine dioxide, with wood dust, carbon disulphide* and calcium oxide dust not uncommon^{5, 6}. Similar results were found in a hygiene survey of a Canadian ECF mill, with chlorine compounds the main airborne exposures in the workplace for ECF mills. The authors noted that although elemental chlorine is not used in ECF mills, it was still found to be present in more work areas than chlorine dioxide, and significant exposures can still occur during breakdown in processes⁷. Exposure also occurs to hydrogen sulphide, methyl mercaptan, dimethyl sulphide⁸, asbestos^{9†} and organochlorines¹⁰.

In non-production areas, such as maintenance and power generation, exposures include asbestos, copper, mercury, chromium VI compounds, ozone, styrene, sulphur dioxide, trichloroethylene, nitrogen dioxide, welding fumes, carbon monoxide, silica and electromagnetic fields^{11, 12}.

TCF plants do not use chlorine dioxide (or chlorine), with ozone the main bleaching agent used in its place. Therefore, exposures in TCF plants primarily differ from those in ECF plants in that there is no exposure to chlorine and chlorine-based compounds, and a much higher chance of significant exposure to ozone¹. Chlorine-based compounds include organochlorines, to which ECF workers are exposed but TCF workers should not be exposed, or at least not at significant levels. Organochlorines, in the context of pulp mills, constitute a complex mixture of by-products that arise from reactions between chlorine dioxide (and chlorine if it is used) and the chemical components of the pulp being bleached. The major components of pulp mill organochlorines are chlorinated lignin fragments, chlorinated phenols and chlorinated cellulose and hemicellulose fragments. Also present in the mixture of by-products are minute quantities (part per quadrillion levels in the case of ECF mills) of polychlorinated dibenzodioxins and dibenzofurans, commonly referred to as "dioxins".

* Carbon disulphide is used when making rayon from dissolving pulp. It is not used as a process chemical in either ECF or TCF bleached kraft pulp mills.

† It should be noted that asbestos exposure is a legacy of the former use of this material in asbestos-cement building products and related materials. Asbestos is not used in modern ECF or TCF bleached kraft pulp mills.

4. HEALTH EFFECTS OF WORK IN PULP MILLS

4.1 INTRODUCTION

As mentioned earlier, pulp and paper mills are often adjacent to each other. Therefore, workers at pulp mills may be exposed to exposures associated only with the paper mill (and vice versa). In addition, it is not uncommon for workers to move between the two mill types. Finally, this co-existence of mills has meant that studies of health effects have often included both pulp mill workers and paper mill workers together. Health effects specific to pulp mill exposures and pulp mill workers can therefore be difficult to identify.

4.2 OVERALL HEALTH EFFECTS

Several studies have examined the overall mortality and/or morbidity of pulp mill workers. All have included paper mill workers in the study group, and all were based on mills using the ECF process. Compared with the general population, pulp and paper mill workers have been found to have a lower total mortality from all causes¹³⁻¹⁶.

4.3 RESPIRATORY DISORDERS

Introduction

Pulp mills have several exposures that are known to be strong respiratory irritants. The main ones are chlorine, chlorine dioxide, sulphur dioxide, hydrogen sulphide, methyl mercaptan and dimethyl sulphide and ozone. Exposure to irritants can cause a variety of respiratory symptoms such as nasal irritation, watering of the eyes and cough. It can also exacerbate pre-existing asthma, causing wheezing. There is increasing evidence that exposure to high levels of irritant gases can predispose the worker to developing asthma. Whether this bronchial hyper-responsiveness is long-term or permanent is not certain¹⁷. This condition of non-specific bronchial hyper-responsiveness following high exposure to respiratory irritants (as occurs with a "gassing" in a pulp mill) is known as Reactive Airways Dysfunction Syndrome (RADS)^{18, 19}. Asthma and asthma-like symptoms have therefore been a common focus of studies of pulp mill workers.

Identified problems

Compared to non-pulp mill workers, pulp mill workers have been found to have:

- increased risk of mortality from asthma²⁰;
- increased incidence of asthma^{21, 22};
- increased wheezing and chest tightness^{23, 24};
- decreased lung function²⁴; and
- increased airways inflammation, as measured by exhaled nitrogen oxide (NO)^{24, 25}.

Workers exposed to lime dust in pulp mills have also been found to have decreased rates of nasal clearance, indicating damage to the epithelial lining of the nose²⁶.

Compared to workers who had not been gassed, workers who have been gassed have:

- increased prevalence of asthma²⁵;
- increased incidence of asthma^{21, 27};
- increased wheezing and chest tightness; and
- decreased lung function^{24, 28-33}.

The majority of the relevant studies were based on ECF pulp mills, where the main problem exposures were chlorine and chlorine dioxide, although there was also sometimes exposure to sulphur dioxide and occasionally to ozone. Some studies were based on Scandinavian pulp mills where ECF technology was replaced by TCF technology, with workers often having worked with both technologies and so having had significant exposures to chlorine, chlorine dioxide and ozone (as well as sometimes to sulphur dioxide). However, several studies included only, or focussed on, workers with only one of these exposures. These studies showed that workers exposed to either chlorine dioxide (or chlorine)^{20, 21, 23, 27-32, 34} or ozone^{24, 25} have increased risk of the respiratory abnormalities described above.

The risk is higher in persons who have been gassed one or more times compared to persons who have not been gassed. Gassing appears to be, or at least to have been, a common occurrence, with the percentage of workers included in the studies who had been gassed at least once ranging from 25% to 60%^{22, 29-32}. The definition of a "gassing" in these papers was essentially an incident where a worker reported exposure to a "high level" of irritant gases resulting in respiratory symptoms, although one study measured ozone levels over 0.9 ppm on six days in one year of consecutive measurements and estimated that ozone exposures could briefly be as high as 10 ppm²². Therefore, the exposure conditions are likely to have varied between different "gassing" incidents included in these papers.

4.4 CANCERS

Introduction

Work in pulp mills entails exposure to many substances that have been identified as definite, probable or possible carcinogens. These include formaldehyde, sulphuric acid mist, sulphur dioxide; asbestos, organochlorines, arsenic, chloroform, biocides, hypochlorite, wood dust, and electromagnetic fields^{11, 35-38}.

The studies that considered cancer incidence or mortality by necessity covered cohorts of workers who are followed for at least a decade after exposure, and often many decades. This is necessary because of the latency between when exposure occurs and cancer can be expected to develop. Therefore, none of the available studies are based on TCF mills, because these mills have not been in operation long enough to have a relevant worker cohort to study. In addition, many of the workers in TCF mills will have previously worked with ECF processes.

Most of the studies included both pulp mill and paper mill workers (and sometimes associated workers). Separate results for the two groups were rarely provided, although some studies did do so, or provided evidence that the results were similar for both groups.

Identified problems

Compared to the general population, or another appropriate comparison population, pulp mill workers and paper mill workers have been found to have lower, or similar, incidence of and mortality from all cancers combined^{13-16, 39-41}.

The majority of studies have consistently found an increased incidence or mortality from:

- lung cancer^{14, 38, 40-45};
- pleural cancer (predominantly mesothelioma)^{35, 36, 42, 43, 45, 46}; and
- stomach cancer^{36, 40, 45, 47, 48}.

Other malignancies that have been linked to exposures at pulp (and paper) mills include:

- brain tumours (and gliomas in particular)^{20, 35, 42, 49};
- nasal tumours⁴⁴;
- leukaemia^{34, 36, 38, 45};
- Hodgkin's lymphoma³⁵, non-Hodgkin's lymphoma³⁸ and cancer of the lymphopoietic tissues^{41, 45, 50, 51};

- oesophagus³⁵, liver or biliary tract⁴², pancreas^{28, 40}, large intestine¹⁵ or rectal carcinoma^{36, 51}, or all digestive carcinomas combined^{28, 50, 51};
- kidney carcinoma³⁵;
- peritoneal cancer (mesothelioma)⁴⁴;
- melanoma^{36, 43};
- prostate carcinoma^{16, 36}; and
- testicular carcinoma⁵².

It is very likely that the most of the increased risks of lung cancer and mesothelioma are related to asbestos exposures in the mills^{9, 35, 36, 42, 43, 46}. Several studies have examined the role of other specific exposures, such as sulphur dioxide³⁸, organic dust⁵³ and organic chlorinated compounds⁵⁴, with lung cancer, but the evidence is weak. None of the other tumours have been convincingly linked to specific exposures within the pulp mills, although the mills have exposures that have been associated in other settings with increased risk of one or more of these tumour types. For some tumour types, the increased risk is probably related to confounding[‡], because information on important factors such as smoking and dietary intake was rarely available.

The studies identifying an increased of lymphoma are of particular interest, since non-Hodgkin's lymphoma has been closely linked to dioxin exposure in other settings. A review in 1996 stated that "An increased risk for malignant lymphomas among pulp mill workers is a constant finding."⁴⁵, but not all recent studies have identified such an increased risk. In addition, non-Hodgkin's lymphoma has not been linked specifically to organochlorine exposure in pulp mill workers. Therefore, the situation with respect to non-Hodgkin's lymphoma in pulp mill workers in general and specifically to organochlorine exposure in pulp mills, remains uncertain.

4.5 OTHER HEALTH EFFECTS

Apart from respiratory disorders and cancers, the occurrence of cardiovascular disease has been studied in pulp mill workers. Excess risks were found in one study in association with exposure to hydrogen sulphide and organic sulphides. Smoking did not appear to explain the increased risks observed⁵⁵⁻⁵⁷. The importance of this finding in a single work cohort is not clear.

‡ Confounding describes the situation where an apparent association between an exposure and a disease is actually due to the presence of another exposure. A common example is a chemical apparently causing an increased risk of lung cancer in a group of workers, but the increased risk really being due to the fact that a lot of the workers smoke.

5. COMPARING THE HEALTH EFFECTS OF WORK IN ECF AND TCF PULP MILLS

5.1 INTRODUCTION

There are no studies that compare health effects in workers involved in ECF pulp mills as opposed to TCF pulp mills. The main difference between ECF and TCF processes in terms of worker exposure is that TCF processes do not use chlorine or chlorine dioxide, but use considerably more ozone than ECF processes. The lack of chlorine use also means that organochlorines are not produced as part of the TCF process. All other things being equal, if there are differences in health effects, they can be expected to relate to these differences in exposure.

5.2 RESPIRATORY EFFECTS

Chlorine, chlorine dioxide and ozone (as well as sulphur dioxide) are all potent respiratory irritants. As shown in Section 4.3, all have been associated with respiratory symptoms of irritation, asthma-like symptoms, diagnosed asthma and worsening respiratory function. Whether such disorders are sustained by the workers will depend primarily on the level of exposure they have to these gases, and how many acute exposures to high levels (gassings) they experience. The pathological effects are likely to be primarily due to the level of exposure, rather than to the type of respiratory irritant involved, since all are very powerful irritants. The level of respiratory problems in the workforce will therefore depend on how well contained, and maintained, the pulp bleaching process is, rather than on whether the process uses chlorine dioxide or ozone. If one process is less subject to gas leaks and high worker exposures, then that process is likely to be associated with lower levels of respiratory disorders amongst the workers. Therefore, no significant differences should be expected in the level of respiratory symptoms or disorders in workers from ECF mills compared to TCF mills, provided that the level and extent of leaks is similar.

5.3 CANCERS

Pulp mill workers are probably at increased risk of developing lung cancer and mesothelioma, and most of this increased risk probably arises due to exposure to asbestos^{9, 35, 36, 42, 43, 46}. There is some inconsistent evidence about increased risk of lung cancer related to exposure to sulphur dioxide³⁸, the kraft process¹⁴, and inorganic dust⁵³.

This is not likely to be related to the mill process (i.e. to be greater in ECF or TCF mills), except that newer equipment and newer plants are unlikely to contain or use asbestos.

Stomach cancer is the only other cancer consistently associated with pulp mill work. Much of this increased risk may be related to confounding from diet. Increased risks of stomach cancer have been linked to exposures in pulp mills such as sulphur dioxide, sulphuric acid mists and calcium oxide³⁶, but no direct link has been made between these exposures in pulp mills and increased stomach cancer risk in pulp mill workers. These exposures are unlikely to differ between ECF and TCF processes. Presuming these exposures do not differ, there is unlikely to be difference in the risk of stomach cancer in workers using one process in comparison to another.

The one area of difference between ECF and TCF that may lead to differing cancer risks relates to organochlorines. These are produced during the chemical stage of pulping in ECF mills, but do not occur in significant quantities in TCF processes. Organochlorines are released into the atmospheric and waste water environment, so low-level worker exposure is not uncommon. Worker exposure may be greater dermally than via inhalation¹⁰.

Organochlorines (mainly dioxins) have been associated with a wide range of health effects. The only definite adverse health effect arising from dioxin exposure is chloracne (a skin disorder characterised by the occurrence of pustules, commonly on the face and neck), but there is strong evidence linking exposure to soft tissue sarcoma and non-Hodgkin's lymphoma. Some organochlorine pesticides, that are chemically different to the organochlorine by-products produced in ECF bleached pulp mills, have also been linked to leukaemia, lung cancer and breast cancer, and less commonly to a range of other cancers⁵⁸⁻⁶⁰.

Only one study has explicitly examined the relationship of exposure to organic chlorinated compounds in pulp mills and the occurrence of cancer. This study, based on low numbers of cases, found increased incidence of lung cancer in pulp and paper mill workers, especially those who had worked for at least 15 years in the mill. Smoking probably accounted for some of the increased risk, but the authors concluded that part of the increased risk may well have been due to exposure to organochlorines⁵⁴.

There are no case reports documenting pulp mill workers suffering from chloracne, indicating that the level of exposure to dioxins in pulp mills is unlikely to be high. There is a single case report linking soft tissue sarcoma with work in pulp mills⁶¹ and, as mentioned previously, equivocal evidence about increased risk of non-Hodgkin's lymphoma.

If considerable exposure occurred in ECF mills to organic chlorinated compounds, then workers at those plants could be expected to have an increased risk of developing some cancers, particularly soft tissue sarcoma and non-Hodgkin's lymphoma, compared with workers at TCF mills. However, such exposure is not likely in modern mills. It is reasonable to expect that implementation of best practice Occupational Health, Safety and Environmental (OHSE) standards would include measures that effectively eliminate human contact with process streams containing these materials, and measures such as the wearing of gloves that are impervious to chemicals, eye and face shields and efficient exhausting of vapours from spaces above bleaching equipment are standard in modern pulp mills.

6. DISCUSSION

The aim of this report was to consider the different health effects that might arise from work in ECF pulp mills compared to TCF pulp mills. Unfortunately, there are no studies directly comparing workers from these two plant types. Comparison could therefore only be made on the basis of the likely exposures arising from processes in the two plant types, and the health effects linked to those processes.

The exposures in the two plant types appear to be similar, with the only significant difference arising from TCF mills replacing chlorine dioxide with other bleaching agents, particularly ozone. This means that ECF workers are exposed to chlorine and chlorine dioxide, but only to ozone in small amounts. In contrast, TCF workers have potentially high exposure to ozone, but no exposure to chlorine and chlorine dioxide. However, since these gases are all highly irritant, the effect of exposure to them is much the same, and there was no evidence available relating the likelihood of significant exposure to at least one of these irritant gases (or sulphur dioxide, another irritant gas to which workers in both mills are exposed) in one mill type compared to another.

The only other important exposure that seemed to differ between the two plant types is organochlorines, which include dioxins. These compounds have been associated with a range of health effects, particularly several forms of cancer. There were many studies of cancer occurrence in pulp mill workers, but all considered workers who had been working in plants for a decade or more, and all covered workers at ECF mills. None considered workers who had only worked in TCF mills, as these mills had not been operating long enough to allow appropriate worker cohorts to be identified and studied.

A complicating factor in interpreting the study results is that pulp mills have often converted from ECF to TCF technology, with the same workers working on both processes. Therefore, current health problems in TCF mills may be a result of exposures that occurred during work with ECF processes. Also, pulp mills often occur in close proximity to paper mills, or may be part of one large pulp and paper mill, and workers may move between the two areas. Therefore, workers in the pulp mill may develop ill health because of exposures experienced while working in the paper mill. Finally, many of the concerning exposures occur in maintenance areas. These exposures are not likely to differ between ECF and TCF plants, as the maintenance work is likely to be similar. Therefore, some of the health problems identified in cohorts of pulp mill workers are likely to be due to ill health in maintenance workers and not to be specifically relevant to the ECF or TCF process.

Most of the studies of respiratory health compared pulp mill workers with paper mill workers or other unexposed workers. Smoking is a very important cause of respiratory problems, and so is commonly an important confounder (a factor that causes the study results to be misleading) in any study of respiratory health problems. The effect of smoking on the study results can be minimized by collecting information on smoking history and taking this into account in the study design or analysis. Some of the studies were able to collect such information, but some were not, making the interpretation of some of the study findings difficult.

This was more of a problem for the studies of cancer. Nearly all of these compared the cancer incidence or mortality in plant workers with that of the general population, or sometimes with the local regional population. Such analyses take into account age, but do not allow other potentially important confounders, such as smoking, diet or important occupational exposures, to be taken into account.

These problems with confounding are unlikely to have influenced the main aspect of this report, which was the comparison of health effects in ECF mill workers compared to TCF mill workers. However, they do need to be kept in mind when considering the significance of any apparent association between pulp mill work and ill health, especially related to cancer occurrence.

7. SUMMARY

There are no studies that directly compare the health status of workers at ECF plants compared to those at TCF plants. The main difference in exposures between the two plants is the use of chlorine dioxide in ECF plants, leading to exposure to potential exposure to chlorine dioxide, chlorine and organochlorines. In TCF plants, there is higher potential exposure to ozone, but no exposure to chlorine dioxide or chlorine, and little likelihood of exposure to organochlorines.

It is likely that there are no major differences in non-malignant respiratory disorders, since chlorine, chlorine dioxide and ozone are all potent respiratory irritants. If considerable exposure occurred in ECF mills to organic chlorinated compounds, then workers at those plants could be expected to have an increased risk of developing some cancers, particularly soft tissue sarcoma and non-Hodgkin's lymphoma, compared with workers at TCF mills. However, such exposure is not likely in modern mills.

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