Survey of construction workers repeatedly exposed to chlorine over a three to six month period in a pulpmill: I. Exposure and symptomatology

Jean-Pierre Courteau, Robert Cushman, Françoise Bouchard, Michelle Quevillon, André Chartrand, Luc Bhérer

Abstract

Objective—The admission to hospital of three construction workers with acute respiratory distress caused by inhalation of chlorine gas prompted the inspection of a building site located in a kraft pulpmill. The accidental emissions had taken place in the bleach plant and the construction workers assigned there were surveyed to uncover possible large scale health effects.

Design and participants—A questionnaire was presented to 281 workers (participation rate = 97%); 257 workers reported an average of 24 exposure episodes to chlorine and derivatives over a three to six month period. The air monitoring data available from the pulpmill's industrial hygienist were not useful in linking specific events reported by the workers to environmental conditions in the bleach plant.

Results—Over 60% of the workers described a characteristic flu like syndrome that lasted for an average of 11 days and was exacerbated by new bouts of exposure. Irritation of the throat (78%) and eyes (77%), cough (67%), and headache (63%) were the most often reported symptoms. Shortness of breath was reported by 54% of the participants and was not associated with age, smoking state, or history of asthma or chronic bronchitis. First aid self referral was associated with significantly greater reporting of most symptoms, including dyspnoea and cough. A significantly greater proportion of workers in the dyspnoea group had gone at least once for first aid care after a gassing incident (64% as opposed to 48%, p = 0.008). Throat irritation and cough persisted for mean intervals of eight and 11 days respectively. A flu like syndrome lasted for an average of 20 days. Seventy one subjects were considered to be at moderate to high risk of having persistent respiratory symptoms.

Conclusion—Throat and eye irritation as well as cough and flu like symptoms are frequent occurrences after repeated accidental inhalation of chlorine. Subjects who consulted first aid care stations after a gassing incident are more likely to have persisting dyspnoea.

Pulpmill workers can be exposed to various gases and particulates such as chlorine, chlorine dioxide, hydrochloric acid, sulphur dioxide, hydrogen sulphide, and wood dust.12 Of these, chlorine and chlorine dioxide are potentially the most harmful to the bronchi and lungs. Pulpmill workers who are not exposed to these two gases do not seem to develop chronic respiratory problems.3

Under normal circumstances, exposure to chlorinated gases in pulpmills is minimised by the use of a closed system in which liquid chlorine from rail tank cars is conveyed through complex piping to the bleach plant system. Engineers and industrial hygienists acknowledge, however, that the accidental release of chlorine or chlorine dioxide is a frequent occurrence as a result of leaks, unstable operating conditions, human error, equipment malfunction, and other unexpected events. The air monitoring strategies currently used in pulp and paper mills do not completely eliminate the risk of exposure as a result of accidental emission.

Chlorine has a pungent odour that can usually be detected at concentrations of less than 0.5 ppm, although some workers chronically exposed to the gas become anosmic.4 The acute manifestations associated with exposure to high doses of chlorine have been well documented, but the long term effects remain unclear. Most of the available publications suggest that a single heavy inhalation of chlorine gas in a non-industrial setting does not generally result in chronic changes in respiratory function.5-10 Some subjects exposed to higher concentrations, however, may show persistent airways obstruction. Furthermore, in the studies mentioned, assessment of non-specific bronchial responsiveness had not been carried out to disclose the possibility of persistent asthma. A follow up study of 20 construction workers who had been exposed to chlorine gas showed that five of 13 tested workers had bronchial hyper-responsiveness to a non-specific pharmacological agent (methacholine) 12 years after the initial event.11

Exposure to high concentrations of respiratory irritants such as chlorine is believed to cause an asthma like syndrome in some subjects, accompanied by bronchial hyper-responsiveness. It was first described by Brooks et al in 1985 and termed reactive airways dysfunction syndrome.12 13 This condition, also referred to as irritant induced asthma,14 is characterised by the presence of non-specific bronchial hyper-responsiveness
Material and methods

DESCRIPTION OF THE EVENTS

The survey and a concurrent investigation by the Quebec Workers’ Compensation Board (Commission de la santé et de la sécurité au travail du Québec, CSST) were initiated after three construction workers were admitted to hospital on the same day for respiratory distress caused by acute exposure to chlorinated compounds. These sentinel events received extensive media coverage and the crisis which unfolded had many of the characteristics of a public health disaster. The size of the exposed population and the relatively large number of exposures reported over a short period of time are unusual in medical publications.

The renovations to the kraft pulpmill began in January 1989. In January 1990 they extended to the most dangerous sector of the mill—namely, the bleach plant. Because they were unfamiliar with their new environment, the construction workers assigned to the bleach plant were given specific information on the dangers of irritant gases and were instructed to carry a cartridge mask with them at all times. They were also told to leave the bleach plant immediately if they detected any irritating odour or if an alarm was triggered.

A total of about 700 construction workers were involved at one time or another in the renovations. Twenty three different companies were active in various parts of the pulpmill, but only one (referred to as the target company) was assigned to the bleach plant, where its workers performed welding and pipe-fitting operations. Chlorine dioxide production and construction took place simultaneously for almost three months. The bleaching operations were interrupted only on 25 March 1990, by order of the CSST.

A review of the first aid register showed that about 100 different workers had received first aid treatment for gassings involving chlorine and its derivatives between 1 January and 25 March 1990. Many workers reported to the first aid station more than once. Over 95% of all gassing incidents reported involved workers of the target company. Most workers went back to the job after a treatment consisting of “antichlorine syrup” and coughdrops. A few workers received oxygen by mask and an undetermined number had to leave work temporarily or permanently because of severe or persistent symptoms. Most gassing accidents occurred in clusters and were attributed by the workers to mild detonations in the chlorine dioxide generator (“puffs”).

ENVIRONMENTAL ASSESSMENT

The chlorine dioxide used in the bleaching process was manufactured at the mill site using the modified Mathieson Erco process, which has been shown to carry a risk of accidental emissions of chlorine and chlorine dioxide. The air monitoring data collected over the three month study period in the bleach plant were provided by the pulpmill’s industrial hygienist. We asked the provincial research institute in occupational health and safety (Institut de recherche en santé et en sécurité du travail du Québec, IRSSST) to examine the results for us and to comment on the sampling techniques and strategies used by the company.

STUDY POPULATION

All workers employed at one time or another at the pulpmill site by the target company were eligible and were asked to participate. The company provided a list of names of all the workers who had appeared on its payroll since 1 January 1990. As of 21 March 1990, 229 workers were still at the pulpmill and 60 others were on different construction sites or were no longer employed by the company (fig 1). All 229 on site workers agreed to participate in the survey, and 52 of the 60 others were contacted and answered the questionnaire by telephone. Only eight former workers (2.8%) could not be reached and did not participate in the study.

QUESTIONNAIRE

A questionnaire was developed to collect information on the number of gassing incidents reported by each worker. The questionnaire specified that the exposure of interest
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PHYSICIAN ASSESSMENT
Six occupational health physicians were present in teams of two during the on-site interviews. They reviewed each completed questionnaire and interviewed each worker briefly to determine if any persistent symptoms were present. Finally, a short physical examination was performed and abnormal respiratory signs including lung sounds were specifically described and recorded.

ANALYSIS OF RESULTS
The SYSTAT statistical package (release 5.0 for the MacIntosh, Evanston, IL 60201) was used to process data. Independent sample t tests and Pearson χ² tests were used for the statistical analyses. A p value < 0.05 was considered significant.

Results
ENVIRONMENTAL ASSESSMENT
The air monitoring data available from the pulpmill's industrial hygienist were not useful in linking specific events reported by the workers to environmental conditions in the bleach plant. Experts from the IRSS developed the data in April 1990 and stated in their report that almost all the air samples taken in the bleach plant had been drawn after the fact, to determine if evacuated workers could return after a gassing incident. The investigators also concluded that more than 65% of the air samples were not valid because of technical flaws and errors.

The time weighted and ceiling threshold limit values (TLVs) for chlorine in Quebec are 1 ppm and 3 ppm respectively, and the corresponding TLVs recommended by the American Conference of Governmental Industrial Hygienists are 0.5 and 1 ppm. A total of 483 samples were taken for chlorine in the bleach plant. Thirty-six percent of the samples showed chlorine concentrations of less than 0.5 ppm, 58% were between 0.5 and 8 ppm, and 6% were over 8 ppm. No samples were taken for chlorine dioxide.

There were permanent monitors in the bleach plant that were set to automatically trigger a visual alarm at 3 ppm of chlorine. It was determined, however, that the electrochemical sensors used in the monitors were not specific and that other gases such as chlorine dioxide, hydrochloric acid, carbon monoxide, and sulphur dioxide could have reduced their sensitivity to chlorine.

DEMOGRAPHIC DESCRIPTION AND WORKERS' MEDICAL HISTORY
A total of 281 of 289 (97%) workers participated in the study (fig 1). Their average age was 44 years, with a range from 18 to 69 years, and 81% were either welders or pipefitters. Smoking history was as follows: 150 workers (53%) were current smokers and 84 were ex-smokers; 42 workers said that they had never smoked. Twenty workers (7%) reported chronic lung disease diagnosed by a physician (asthma or chronic bronchitis) and nine were using bronchodilators; eight

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Figure 1: Flowchart of the sequential steps in the study design.

- Worksite: Pulpmill
  - 23 companies
  - with 700 construction workers

- 22 companies (non-participants)

- Target company: 289 workers

- Still on site: 229 workers

- No longer on site: 60 workers

- Questionnaire (n = 229)
  - Questionnaire by phone (n = 52)
  - Lost to follow up (n = 8)

- Unexposed (n = 24)
  - Low risk (n = 186)
  - Moderate risk (n = 46)
  - High risk (n = 25)

- Follow up study

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was to yellow or green gases with a pungent bleach like odour. We also asked each worker who had come into contact with these gases more than once to identify the single most significant episode and to recall the symptoms experienced after that episode. Symptoms that were documented were those spontaneously reported by employees who initially visited the first aid department. There were 68 occurrences of nose and eye irritation, 37 of shortness of breath, 32 of headaches, 27 of cough, 17 of eye irritation only, 13 of abdominal pain or nausea, six of dizziness, six of excessive sweating, four of weakness, and one of taste alteration. Wheezing was not included as it was not spontaneously reported at the time of the initial events. Each worker was also asked to estimate the duration of each of the symptoms reported and the number of times he recalled having been evacuated from the bleach plant because of gassing alerts. Finally, the questionnaire investigated the use of first aid care, medical or hospital services related to gassing incidents, and relevant pre-existing medical conditions (lung and cardiovascular diseases, allergic rhinoconjunctivitis, medication).

The questionnaire was presented on site by three public health nurses familiar with occupational settings. The bleach plant was closed down on 25 March and the on-site participants were questioned on 28 and 29 March 1990. The questionnaire was also presented by telephone in subsequent weeks to the 52 workers who had left the site.

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reported diagnosed cardiac disease and 29 reported allergies to foods, animals, and dust, or said that they suffered from seasonal hay fever. Thirty three workers said that they were currently taking medication (other than bronchodilators) prescribed by a physician.

ASSESSMENT OF EXPOSURE
Twenty four of the 281 workers questioned reported no contact with any chlorinated gases during the period that they were employed by the target company. They were either office personnel or support staff who did not have to work regularly in or around the bleach plant. The remaining 257 workers reported an average of 24 evacuations (either spontaneous or triggered by an alarm) over the three month study period, and an average of 25 gassing episodes. These episodes became more and more frequent from January to March 1990, and the number of incidents resulting in exposure culminated in the two weeks before the beginning of our investigation. Of the 257 workers exposed, 192 had worked exclusively in the bleach plant and 23 had worked in other sectors of the pulpmill as well. Forty two workers were never assigned to the bleach plant and reported exposures that occurred in other sectors of the pulpmill. Interestingly, nine of the 52 workers who had left the building site at the time of the survey said that they had left their jobs because of health problems caused by irritant gases.

SYMPTOMATOLOGY
Figure 2 shows the proportions of participants who reported various symptoms associated with their single most significant exposure to chlorinated gases. Irritation of the eyes and throat, as well as cough, were those most often mentioned. A flu like syndrome, with nose and sinus congestion, headache, fatigue, cough, and shortness of breath (especially at night) was typically described. Symptoms of wheezing and anosmia were not specified in the questionnaire.

Thirty seven per cent of participants said that they had difficulty sleeping. In most cases that seemed to be related to exposure this was associated with paroxystic nocturnal coughing. Fifty six per cent of the 150 workers who were current smokers said that smoking had become distasteful or irritating. Eleven of the 82 ex-smokers said that they had stopped smoking while working on the site because smoking had become unpleasant.

Figure 3 shows the average duration of each of the symptoms reported after the most significant exposure episode. Immediately after being in contact with chlorine gas, the workers typically experienced short lived eye irritation, dizziness, and nausea. Some workers reported choking and falling to their knees before being able to evacuate the bleach plant. These symptoms resolved quickly but within hours the gassed workers usually developed the characteristic flu like syndrome. Many workers said that they experienced an usually long flu during the entire time they worked on the site.

USE OF FIRST AID AND MEDICAL CARE
One hundred and four workers said they had been to the company’s first aid clinic following a gassing accident. First aid self referral was associated with a significantly greater reporting of all symptoms except for distaste for smoking and flu (table 1). Thirty eight workers reported at least one visit to a physician in the community, 24 had gone to a hospital emergency room, and nine workers (3.2%) had been admitted to hospital after a gassing incident.

FACTORS ASSOCIATED WITH DYSPNOEA
We considered dyspnoea as a marker of lower respiratory tract irritation and as a risk factor for developing chronic lung disease after exposure to chlorinated gases. Workers in the dyspnoea group and those in the non-dyspnoea group did not differ according to age (independent samples t test, p = 0.634), previous history of asthma or chronic bronchitis (Pearson $\chi^2$, $p = 0.089$), or smoking state ($p = 0.116$). A greater proportion of workers in the dyspnoea group had gone at least once for first aid care after a gassing incident (64% v 48%, $p = 0.008$).
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Table 1  Association of first aid self referral and symptoms

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>x²</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal pain</td>
<td>5.9</td>
<td>0.02</td>
</tr>
<tr>
<td>Excessive sweating</td>
<td>4.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Nausea</td>
<td>22.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Difficulty sleeping</td>
<td>9.3</td>
<td>0.002</td>
</tr>
<tr>
<td>Dizziness</td>
<td>8.8</td>
<td>0.003</td>
</tr>
<tr>
<td>Tarse alteration</td>
<td>10.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Fatigue</td>
<td>15.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>7.1</td>
<td>0.008</td>
</tr>
<tr>
<td>Headache</td>
<td>12.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cough</td>
<td>16.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Eye irritation</td>
<td>8.7</td>
<td>0.003</td>
</tr>
<tr>
<td>Throat irritation</td>
<td>13.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Distaste for smoking</td>
<td>2.6</td>
<td>0.11 (NS)</td>
</tr>
<tr>
<td>Flu</td>
<td>1.2</td>
<td>0.3 (NS)</td>
</tr>
</tbody>
</table>

Degrees of freedom = 1 in all instances

Determination of Risk of Chronic Respiratory Problems

All workers were initially classified as either exposed or unexposed. If a worker recalled at least one incident where he detected a characteristic strong bleach odour, he was considered to have been exposed whether he reported any symptoms or not. A set of criteria was developed (table 2) to attempt to predict the long term risks of chronic lung disease in relation to individual exposure to chlorinated gases. A dose dependent relationship for developing reactive airways dysfunction syndrome has been described. As we could not offer a specialised respiratory follow up to all the 257 exposed workers, we classified them according to the degree of their symptomatology. Low risk workers were told to see their family doctor if necessary and were given a letter stating that they had been exposed to chlorine. Moderate risk workers were given the same letter but were instructed to see their family doctor and to have their exposure state specifically recorded. We arranged for an assessment by a respiratory physician for all high risk patients. Only three workers initially classified as low risk and followed up by a primary care physician eventually required a respiratory assessment and specialised follow up. Moreover, the workers in the moderate and high risk groups were enrolled in a prospective study and were offered a thorough respiratory functional assessment.

Table 2  Criteria used to classify the workers according to their risk of chronic lung disease

Low risk:
- Irritant symptoms only, no shortness of breath reported
- Shortness of breath reported after exposure but no longer present, no abnormal lung sounds, no pre-existing illness or medication, and age <50 years.

Moderate risk:
- Shortness of breath reported after exposure but no longer present, significant other medical condition (symptoms of chronic bronchitis, cardiovascular disease, allergy, need for medication) and/or age ≥ 50 years, and no abnormal lung sounds.

High risk:
- Persisting shortness of breath and/or abnormal lung sounds.

Discussion

The pertinent point of our study is that we investigated a population that had been repeatedly exposed to chlorine over a three month period. The symptomatology reported by the construction workers in our survey is consistent with publications on acute and subacute exposures to chlorine and chlorine dioxide. Symptomatic workers all reported exposure to chlorine gas at concentrations above the odour detection level, and after the fact air monitoring data suggest that exposure to high concentrations of chlorinated gases occurred repeatedly. There was no increased influenza activity during the study period, and it is highly unlikely that the symptoms reported were caused by an infectious agent.

We relied on individual workers’ self reports of exposure (gassings) and disease (symptoms). After our decision to survey all the workers employed by one company, we were surprised how few declared no exposure to chlorine. Instead of the 100 or so exposed workers we had expected from our assessment of the first aid register, we found 257 who were exposed and symptomatic. Thus 153 workers who reported gassings had never gone for first aid care. The reason for this is unclear because it has been suggested that first aid reports of acute chlorine gassings among pulp mill workers may be reliable predictors of abnormalities of lung function.

We first supposed that this group was less heavily exposed and less symptomatic, but seven of the 153 workers ended up in our high risk group and 22 in our moderate risk group. All seven high risk workers and one moderate risk worker had bypassed first aid, however, and proceeded directly to a physician in a private clinic or a hospital. That left 21 workers who were gassed repeatedly, who had severe symptoms, or had a relevant medical history, and who had never gone for diagnosis or treatment. There are many possible explanations for this apparent tolerance and stoicism. The acute and subacute symptoms experienced were non-specific and could have been mistaken by many for a cold or flu. Also, more than half of the workers on the site came from remote areas and were not familiar with local community health services. The first aid clinic was staffed by nurses and by a part time physician employed by the pulp mill, and the construction workers might have been hesitant to ask for services. First aid personnel often qualified the gassings as harmless, and the workers returned to work after a treatment consisting of syrup and coughdrops. Many workers, knowing this, refrained from consulting the first aid staff in favour of self medication. Finally, some workers may have been afraid of losing their jobs or simply believed that they would recuperate on their own.

The workers were informed before the survey that they could be entitled to financial compensation, and this could have induced over-reporting. The magnitude of this potential bias could not be assessed. As mentioned in the method section, we designed a
questionnaire that was based on key symptoms that were spontaneously reported by workers who came to the first aid department (90 different visits). As wheezing was not reported, this symptom was not included in the questionnaire. It is obvious that symptoms may have been faulty as recording was retrospective in our survey. The nature of symptoms included in the questionnaire was similar, however, to those spontaneously reported by subjects at the time of the visit of the first aid unit. This, we think, would have facilitated the process of remembering symptoms in a retrospective manner.

Dyspnoea occurred in our study at comparable rates among smokers and non-smokers, in old and young workers, among those with asthma, and those without. We can hypothesise that the exposure to chlorine was frequent and heavy enough to override the effects of smoking, age, and medical history in this population.

At least 71 welders and pipefitters who participated in this study are now considered at moderate or high risk of developing chronic lung disease in relation to their repeated exposure to chlorinated gases. They have been enrolled in a prospective study and offered a thorough respiratory functional assessment including level of non-specific bronchial responsiveness.

In conclusion, our findings add to a growing body of publications suggesting that all exposure to chlorine and chlorine dioxide be avoided. There are no individual risk factors, nor are there any characteristics that can accurately predict which workers will develop serious symptoms after repeated exposure to chlorinated gases. In the light of our study, we assert that the preventive measures currently used in the pulp and paper industry failed to protect the health of construction workers assigned to an unfamiliar environment. To prevent the occurrence of “epidemics” such as the one described here, it is perhaps important to challenge the widespread practice of maintaining chlorine dioxide production in pulpmills in which renovations are taking place.

We thank Jose Lopes-Nunes, Francine St-Denis, and all the members of the survey team for their invaluable assistance. We also thank those responsible at the Quebec Workers’ Compensation Board (Commission de la santé et sécurité du travail) and the Institut de recherche en santé et sécurité du travail for their support and expertise. We are grateful to Jean-Luc Malo, MD, Associate Professor of Medicine, Université de Montréal School of Medicine and Fonds de la recherche en santé du Québec, and to Katherine Tallman for reviewing the manuscript.
