

CHLORINE EXPOSURES AND WORK HISTORIES FOR PARTICIPANTS
IN THE "PROSPECTIVE STUDY OF THE EFFECTS OF
CHRONIC CHLORINE EXPOSURE IN MANUFACTURING ON
RESPIRATORY HEALTH"

INTERIM SUMMARY: 1984 AND 1985

J. S. PAUL
B. D. LANDENBERGER
and
S. K. NORWOOD

The Dow Chemical Company

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PURPOSE

This interim report summarizes the 1984-85 chlorine exposures and work histories for participants in The Dow Chemical Company-Tulane University collaborative chlorine study described in the protocol, "Prospective Study of the Effects of Chronic Chlorine Exposure in Manufacturing on Respiratory Health." This report addresses issues of the protocol that were to be resolved after the first cycle of sampling. Summarizing exposure data and work histories on a yearly basis helps ensure the quality of the data at the end of the study and develops consistency throughout the study.

METHODOLOGY FROM PROTOCOL

Work History

As this is a dynamic employee population and job and plant assignment changes are likely to occur over the five year study period, a prospective work history tracking system will be maintained to provide accurate employee job status information.

Sampling Strategy and Exposure Data Collection

The industrial hygiene sampling strategy has been designed for the first year of this prospective study. At the end of the first year, the sampling strategy will be reevaluated. Modifications may be made in the sample group designations and the number of measurements taken in each sample group.

1. Sample Group Designations

Twenty-one sample groups (twenty exposed and one control) have been assigned based on the tasks performed by the employees and their work locations. After the first year of sampling, these groups may be reassigned by similarities in exposure profiles as well as similarities in work areas and tasks performed.

The study population has also been arranged into four major categories to define the expected potential exposure for each sample group. The personnel in the Chlor-Alkali II and Chlorine plants have been divided into three categories (A, B, C) (Tables 1 and 2) based on the frequency of potential exposure to chlorine. Category A consists of job classifications in areas where the written job procedures require work in which chlorine may be released to the air on a daily basis (e.g., cell crew checking pHs on the chlorine cells).

Category B contains job classifications which perform tasks in different areas of the plant; therefore, depending on the job and area (e.g., instrument person in cell area), an occasional potential for chlorine exposure may arise.

Category C consists of those job classifications which work in an area where a plant problem resulting in a chlorine release could create a potential for exposure (e.g., Technical Engineer in Brine Section).

Category D contains the control populations which consists of the High and Low Density Polyethylene plants. The job classifications in Category D (Table 3) are in the general plant area (e.g., Senior Operating Technician - Reaction).

2. Sampling Scheme

Ten shifts will be sampled for each of the twenty sample groups in the chlorine-producing plants (Tables 1 and 2). While ten samples will be taken per group, some samples may be lost due to equipment failures. In no instance will fewer than five valid samples be acceptable for characterizing a sample group. Replacement samples will be taken as necessary and as personnel constraints permit. A sample size of five to ten should adequately represent the mean and standard deviation of the exposure for a sample group.

It is also expected that some of the sample groups will be pooled at the end of the first year, resulting in larger sample sizes for these groups. Furthermore, it should be possible to pool data from multiple years for most groups, resulting in even larger sample sizes for estimating exposure profiles. The control group (Table 3) will be monitored during ten night shifts and ten day shifts.

Part of the sample groups work eight-hour shifts during the day, while the rest of the sample groups work Twelve-hours shifts and rotate between day shift and night shift (Table 4). Full-shift samples will be taken of all eight-hour shifts which are monitored. Similarly full-shift samples will be taken for the twelve-hour shifts, but only for the first half of the sampling regime. When half of the twelve-hour shifts have been monitored, an interim analysis will be made to determine whether samples should continue to be taken for a full twelve-hour shift or whether the remaining samples can be taken for only half shifts (50% of samples in the first half of the shift and 50% in the second half). Samples for sample groups which work rotating shifts will be evenly divided between day and night shifts. Samples for all sample groups will be divided approximately equally among the quarters of the year. Also, samples within a group will be as evenly divided as possible between all employees in that group.

3. Method of Determining Chlorine Exposures

Each employee to be monitored will wear a belt-mounted leather pouch containing the following equipment: an electrochemical sensor, a data-logger, and a respirator which, when used, will activate a switch indicating respirator usage.

The sensors are the "Wolcott" Nafion membrane type supplied by the Louisiana Division or sensors of equivalent performance. These sensors have been validated to measure chlorine concentrations from 0.05 ppm to 20 ppm with a precision of better than $\pm 25\%$ at the 95% confidence level (Langhorst, 1982). These chlorine sensors are attached to the employee's

collar, near the breathing zone. Each thirty-second average chlorine concentration detected by the sensors is stored in the Metronics datalogger or equivalent. The Metronics datalogger, purchased from Metrosonics, Inc., Rochester, NY, can store up to 2,048 individual thirty-second values (approximately seventeen hours sampling time).

When the respirator is removed from its holster, an electronic signal is received by the datalogger which signifies that the respirator is being used. The hygienist will perform a quality control check on each sample. The quality control check will consist of a hardware inspection, as well as a comparative analysis of the daily sample work sheet to the computer printout for correct calibration, computation and respiratory usage record. All samples will be stored in the computerized raw data file with those passing the quality control check so indicated.

The following five sequential steps are required to generate data: (a) calibrate the sensor, (b) employee wears the equipment package for the sampling period, (c) recalibrate the sensor, (d) transfer the sensor response information in the datalogger to a mainframe computer, and (e) generate an output report. Also, an interview with the employee will be conducted to validate respirator use. Steps a-e are described in detail in the Industrial Hygiene Monitoring Method (IHM), number HEH-IHM-83-34 (Hoffman and Campbell, 1983). This IHM summarizes the validation data for the chlorine sensor monitoring method, describes the procedures for calibration, quality assurance and sensor maintenance. It also contains a computer software Users Manual which discusses storing, retrieving, calculating, and reporting the chlorine exposure data. The sensor response profile will be confirmed prior to each monitoring session as part of the quality assurance procedures, and sensors with abnormal response profiles will not be used.

Also, to help assure the quality of the chlorine exposures data, periodic side-by-side checks with an independent method such as the sulphamic acid reference method or its equivalent will be conducted. The timing and frequency of these checks will be at the discretion of the industrial hygienist but should be at least once each year.

The critical values in the output report are the "actual" time-weighted average for the shift (ppm) and the "actual" dose over threshold (ppm-min). Many threshold concentrations can be selected for the purpose of a priori description of exposure groups.

After one year of sampling data have been collected, the data will be examined, without reference to the pulmonary function data, to determine specific threshold concentration levels which may be examined in statistical analyses. Additionally, these data will be examined to determine the degree of correlation between specific TWA exposures and levels of excursion or peak exposures, as the degree of correlation may impact on the regression model to be utilized in the analysis stage.

Statistical Analysis

Exposure measurement data gathered in 1984 is expected to furnish the following kinds of information:

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1. Clusters of similar job categories with respect to peak exposure, TWA's, etc., may be evident. Combining such clusters will improve the efficiency of the sampling designs in subsequent years.
2. Describing the distributions of exposures in 1984 will allow us to assess the need for subsequent data transformations, and to select testable threshold concentration values and reasonable data ranges for protocol amendments involving hypotheses to be explored at the conclusion of the longitudinal phase.
3. Correlations among various exposure measures will indicate which ones are likely to furnish independent information. For instance, if "peak" and "TWA" exposure are highly correlated, then using both will be redundant.

Additionally, the review of job migration patterns observed during the necessary process of collecting prospective work histories for the groups identified as potentially exposed and unexposed will be valuable in planning future statistical analyses. For example, employee job migration among various dissimilar exposure categories in 1984 may be indicative of subsequent problems in assigning meaningful average exposure indices, and substantial out-migration in 1984 may indicate future problems in participation rates and/or selection bias.

Length of employment is considered as a covariable in order to control for potential exposure to other possible respiratory hazards. Length of exposure may be nearly colinear with age so that using both may over-control. Previous hazardous occupational exposures are considered in order to control for potential confounding caused by occupational exposures received prior to the Dow work history.

An ordinal index of past chlorine exposure is of interest in order to control for the potential influence of historical occupational chlorine exposure on pulmonary function decline. This is necessary in order to insure that a relationship, if any, between pulmonary function annual decline and exposure during the course of this longitudinal study is neither obscured nor magnified by past chlorine exposure. The construction of an ordinal index will be aided by determining the relationship between area exposures and personal exposures during the study period and applying this relationship to past area exposures in order to ordinally estimate past personal exposures. In addition, available anecdotal information will be used.

DISCUSSION AND RESULTS

Work History

A prospective work history system was developed to track the industrial hygiene job assignments in the CA II Plant and the Chlorine Plant. Work histories outside of the CA II Plant and the Chlorine Plant were extracted from the personnel accounting system. The work history

information can be found in Appendix A. Tables 11-13 contain information on the job assignment codes and the associated job classifications. Tables 14 and 14B contain the actual work histories of participants in the study, including work history information prior to 1984. Job distribution information of individuals in the study is handled in a prospective manner, indicating the jobs the individual works until the next entry date.

Sampling Strategy and Exposure Data Collection

Due to difficulties in the initial implementation of the new chlorine sensor technology, the first sampling cycle was conducted over 1984 and 1985, rather than just 1984 as originally anticipated. However, these data may be grouped and applied to both the 1984 and 1985 pulmonary function results. A comparison of the 1984 and 1985 exposure data will be discussed in the Statistical Analysis section.

The quality assurance procedures in the protocol have been followed throughout the study. Since the beginning of the study, additional validation work has been conducted with the chlorine sensor and there is no longer a need to continue periodic side-by-side checks with an independent monitoring method. Therefore, periodic checks against the sulphamic acid reference method have been eliminated. Calibration of sensors prior to and after monitoring will continue as specified in the protocol.

A number of samples were declared invalid by the industrial hygienist doing the survey. These invalid samples were due to electrical/mechanical failures and resulted in unrecoverable invalid data (Table 5). A file containing information on the invalid samples has been maintained and is available for review. A graphical representation of when invalids occurred and for what jobs can be found in Figure 1.

Data transformations were made on the concentration strings from the loggers prior to calculating average exposures in a job assignment. All values less than the detection limit of 0.02 ppm were assigned a value of 0.01 ppm to represent the mean of the values below 0.02 ppm. This procedure was deemed appropriate as the difference between the true mean of the values below the detection limit and 0.01 ppm would be small relative to precision of the measurement technique.

The data were further transformed into three separate data sets based on differing assumptions of respirator usage. The first data set, lowest estimate data, is based on the assumption that there was no leakage during respirator usage and all data values during respirator usage were set to 0.0 ppm.

The second data set, best estimate data, is based on assuming 10% leakage during respirator usage and data values during respirator usage were set to 10% of the original value. This assumption of 10% leakage makes allowance for imperfect respirator fit and the inability of the logger to determine if the person is actually breathing through the respirator; the assumption of 10% leakage is a subjective estimate and may not be accurate.

The third data set, top estimate data, assumes the respirator was totally ineffective and no correction is made to account for respirator usage. Although this assumption provides a poor estimate of exposure, it may provide a better estimate of potential exposure (high, medium, low) if a person changes work practices when wearing the monitoring equipment. A modification in behavior might be expected when the equipment is worn; however, observations of the industrial hygienists have indicated that most individuals disregard the equipment after having been monitored several times.

A final group of data transformations were made to create data sets for calculating exposures above given threshold concentrations. For each threshold concentration represented, the data were transformed by setting each value below the threshold concentration to 0.0 ppm.

The average exposure for a job assignment during a shift was calculated as a time-weighted-average of all the logger values. It was assumed that the string of logger values was representative of the entire shift, even though the monitoring data was sometimes collected for a shorter period of time due to equipment difficulties. The average exposures for the job assignments during 1984 and 1985 are summarized in Table 6.

The estimated exposure to each study participant was calculated separately for 1984 and 1985 by integrating the work history information for each year with the average exposure over both years. The products of the number of days spent in each job assignment and the average exposure in each assignment was summed for each study participant, assuming 1/3 day of exposure for an eight-hour shift and 1/2 day of exposure for a twelve-hour shift. These values were also correct for normal days off in a 2 week cycle (i.e. 10/14 for eight-hour shift and 7/14 for a 12-hour shift). The estimated exposures in ppm-days for the calendar years 1984 and 1985 are summarized in Tables 7-10.

As specified in the protocol, a minimum of five valid samples was collected for each job assignment and monitoring was spread throughout both years. An average of 13 samples was taken for each job assignment (minimum = 5, maximum = 20). The distribution of samples over time is shown in Figure 2.

Statistical Analysis

The protocol specifies reevaluation of the sampling strategy during and after the first sampling cycle. A statistical analysis was to be made of using partial-shift samples rather than full-shift samples for 12-hour shifts. However, once the sampling strategy had been implemented, it was determined that full-shift samples could be taken for 12-hour shifts without creating an unreasonable burden to the industrial hygienist. Therefore, the proposed statistical analysis was not conducted.

An evaluation of the sampling strategy was made at the end of the first sampling cycle. It was determined that a statistical analysis could not be made that would conclusively pool job assignments together so that the number of samples taken could be reduced. A subjective evaluation was

made by the industrial hygienists that the most logical sampling groups had been identified in the protocol and that this sampling strategy should be followed throughout the study.

The protocol specifies that an analysis of data to identify obvious threshold breaks was to be conducted. After reviewing the exposure data, it was determined that the best approach to summarizing the exposure data was to divide the data into multiple intervals so that a distribution of data would be created for future analysis. The exposure tables in this report use this format.

The construction of an ordinal index of exposure based on the relationship of past area samples and current personal/area samples was determined to be technically impossible. Therefore, an index of past exposure will be based on past work histories of the study participants.

The exposure data were divided into two groups; the years of collection 1984 and 1985. For each of the divisions summary statistics for each of the job classification groups were calculated. These summary statistics were then compared on a classification by classification basis to note major discrepancies, see Appendix B. Two of the job classifications, brine treating and power operator, had no measurements in 1985. Of the remaining 11 job classifications, 4 were higher in 1985, 4 were higher in 1984, and the remainder were essentially equivalent. The largest difference between years was a four-fold change. In view of the detection limits of the equipment and expected normal variation, there is no compelling reason that the data should not be combined. It also appears that the issue of combining data from different years is more an issue of policy than statistics, hence no formal statistical test was employed to determine equality of the data from the two years.

A statistical summary of the data can be found in Appendix C. Other analyses specified in the protocol (correlation of TWA's and peaks, data transformations, threshold concentration selections, and job migration patterns) will be evaluated after more data have been collected.