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Exposure Assessment for a Study of Workers Exposed to Acrylonitrile. I. Job Exposure Profiles: A Computerized Data Management System

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In industry-based epidemiologic studies, both air monitoring data and descriptive information are often used in the evaluation of workplace exposures. The format of the descriptive information may vary by plant, department, job title, and year; information on a particular job may often be scattered throughout many documents and may be repetitious. These problems make it difficult to efficiently and systematically assess exposures and document the basis for the assessment. This report describes a computerized data management system that provides a systematic organization of the exposure information collected from various sources at different plants. This computerized system was developed for an epidemiologic study of workers exposed to acrylonitrile to provide documentation of the information that was evaluated to assess exposures. The system was also developed to allow efficient reference as to where that information was found in the study documents and was maintained by unique job/department/plant combinations. The information included items such as a description of the manufacturing process for the department, the tasks and/or duties performed in the job, changes in the department that had a significant effect on exposure levels, the frequency of airborne, peak, and dermal exposures, personal protective equipment use, and the presence of other chemical exposures. This type of data management system could be used in other studies to document collected information or as the basis for maintaining and updating current industrial hygiene records systems. It was, however, developed for use in another computerized system to estimate quantitative levels of exposure. This other system will be described in a future report.

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Introduction

Retrospective exposure assessment is crucial in the investigation of causality of disease and exposure, but it is a difficult and complex process. Where sufficient air monitoring data are available, statistical models can be developed, as has been done in studies of asbestos, silica, and ethylene oxide.[1-3] Unfortunately, most studies do not have sufficient data, and other methods must be used to develop historical estimates. In such studies, the investigator may use descriptive or anecdotal information to supplement the air measurements in assessing exposures. Descriptions of this information have been provided by several investigators,[4-6] and the need to maintain this information in a retrievable manner has recently been stressed.[7-9] No one, however, has described an efficient way to systematically organize and document the large amounts of narrative information often collected in studies.

In an epidemiologic study of workers exposed to acrylonitrile (AN), a systematic approach was developed to assemble, organize, and computerize this type of information that made the information readily accessible to the user making the assessments and to reviewers. The purpose of the study was to investigate the mortality among 27,000 workers exposed to acrylonitrile employed in eight AN-producing or -using plants from the 1950s through 1983. A computerized data management system, called job (and department) exposure profiles (JEP and DEP), was developed that stored exposure and other job-related information (other than air monitoring results) for each job (and department) that might be needed to develop quantitative exposure estimates. This information was linked with a computerized exposure assessment program (EAP) containing air monitoring results used to develop quantitative exposure estimates. This report describes the JEP/DEP data management system.

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Work History Collection and Coding

A complete employment history for each study subject was abstracted from company personnel records. These work histories contained approximately 270,000 job entries. The department and job titles were standardized by department within a plant on the basis of similarity of work areas, environments, tasks, and exposures,[10] resulting in about 3000 standardized job titles requiring an exposure assignment. Plant terminology was maintained wherever possible and no attempt was made to use the same job titles across plants. Thus, the reactor operator in one plant was called the polymer operator in another plant, although both were responsible for the reactors making the polymer.

Exposure Data Collection

Company-generated air monitoring data and descriptive information on exposures were obtained during walk-through surveys of the AN-handling operations, interviews with long-term workers and supervisors at each facility, and from various company records. For AN-handling and support departments, such as maintenance, quality control, shipping, etc., separate discussions were held with groups of two to six long-term production and support workers and with one to three long-term members of the supervisory staff. Two interviews per department were conducted for two reasons. First, this procedure encouraged a more candid interview with the blue collar workers by not having supervisors present. Second, when the information was confirmed from the two different sources, it increased confidence in the data. For each department, a checklist of key items to explore served as a guide for the interviews. The interview covered such topics as a description of the operation, the jobs in the department and the tasks performed in those jobs, personal protective equipment, health effects, changes in the workplace that may have affected exposure levels, and so forth. Historical records, such as plant layouts, job descriptions, etc., were also collected, where available. A site visit report was written after each visit containing a summary of the information collected.[11-18]

The Computerized Data Management System

Each site visit generally resulted in a collection of over 400 pages of paper per plant. The information was in a variety of formats, and often discussed different departments or jobs on the same page. In addition, information about the same department was often present in many different documents. Review of these documents made it apparent that reorganizing the information into a single document organized by job title was impractical.

A menu-driven computer program was designed to provide the organizational framework for the information. Two exposure files were developed: a Department Exposure Profile (DEP) and a Job Exposure Profile (JEP). A DEP was developed for each department and contained information that was common to all jobs within that department, such as process description and production rates. Similarly, for each job title, a JEP was developed that contained information specific to the job, such as frequency of exposure and frequency of peak exposures. In addition, an interactive data entry and access system linking the DEP and JEP files was developed so that entry of an item into the DEP allowed the user to view the data in the associated JEPs.

Prior to using the system, the investigator reviewed the relevant department information for a plant. The appropriate information was then entered into the DEP. The information collected on the jobs in this department was then reviewed and entries made into the JEPs with the DEP information displayed. The system included six screens per job/department/plant (hereafter referred to as "job") into which exposure information was entered. Figures 1 to 6 illustrate an example of a JEP with the DEP information also displayed.

Screen 1 (Figure 1)

The first two fields, job years and frequency, were derived from the job standardization component of the study and were entered from a previously developed computer file. Job years identified the first and last year the job was held by anyone in the plant, and the frequency of the job was the number of times the job appeared in the work histories of the plant. This number was provided to help the industrial hygienist to wisely manage the spent time on each profile.

Data were entered into the remaining fields by the user: process (a description of the process that occurred in the department) entered on the DEP level, location (the area(s) or building(s) in the plant where the job was assigned), and tasks and/or duties (a brief description of the tasks and/or duties associated with the job and the time spent perform-

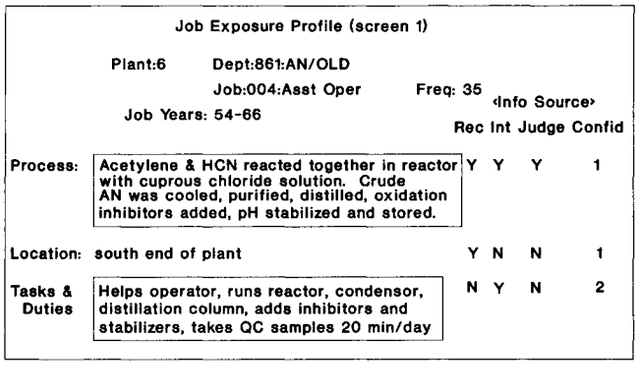

FIGURE 1. Screen 1 identifies job years (years anyone held this job in this department in the study), frequency (number of times this job/department appeared in the personnel records), manufacturing process of the department, location of the job, tasks and duties of the job, the source of information (yes/no) and the confidence (1-4) the assessor has in the information. Rec = record, Int = interview, Judge = judgment, Confid = confidence.

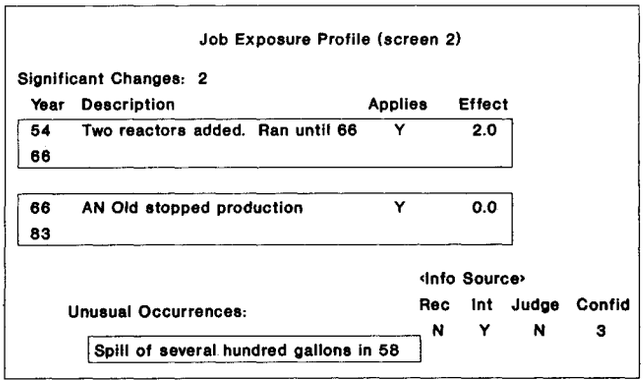

FIGURE 2. Screen 2 identifies the major changes in the workplace (and the years) that occurred over time in the department that may have substantially affected AN exposure levels. "Applies" identifies whether the change affected the particular job. "Effect" is an estimate of what effect the change had on the exposure level; in this case "2" indicates that exposure levels were two times lower before the control was installed. Unusual occurrences in the department are also identified. For details on source of information and confidence, see screen 1.

ing these tasks), which were entered on the job level. For each field on the screen, two additional items were entered: the source of the information and the confidence. The source of the information included records (Rec) supplied by the company, interviews (Int) of employees and/or management, and judgment (Judge). The "confid" column was used to specify a level of confidence (1 = high, 2 = moderately high, 3 = moderate, and 4 = low) the investigator had in the accuracy of the information.

One of the major problems in assessment of historical exposures is the lack of data. Missing data in this study were handled in one of two ways. Where possible, the industrial hygienist used his judgment to complete any field with missing data. The basis for that judgment was documented by entering a "Y" in the judgment field, causing a window to pop up to allow the user to enter either documentation of the source of the information, including the page number(s) of the document, or the basis of the judgment. This allowed for easy review by a second industrial hygienist. Where the industrial hygienist believed the information was insuffi-

TABLE I. Examples of Significant Changes That Were Likely to Have Had a Substantial Effect on Exposure Levels

Date	Significant Change
1965	AN monomer unit started production
1966	Second AN monomer unit started production
1968	Second AN unit shut down for one year
1968	Replaced AN rundown tanks
1969	Replaced previous catalyst with a new one, resulting in a higher number of shutdowns for a year
1975	Incinerator installed for burning off gases. Previously gases went up the stack
1975	Began contracting out more maintenance work
1977	Installed QC sample cabinets
1978	Number of QC samples collected dropped 33%
1978	OSHA standard promulgated
1979	Operators started using sight gauges on barges

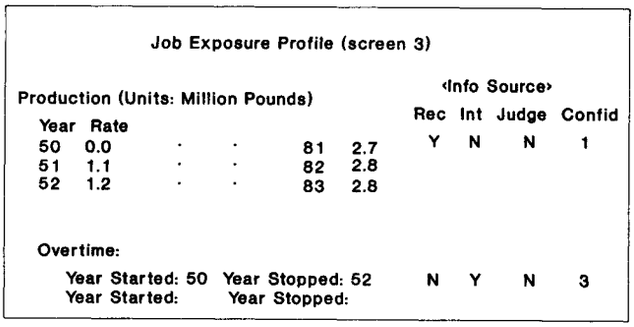

FIGURE 3. Screen 3 identifies the amount of AN or AN product being produced and the years of overtime. For details on source of information and confidence, see screen 1.

cient to even make a judgment, a notation was made in the judgment field signifying the lack of information.

Screen 2 (Figure 2)

This screen had two fields: significant changes and unusual occurrences. The field for significant changes briefly described the major changes in the workplace (and the years) occurring over time in the department that may have substantially affected AN exposure levels. The changes included changes in the process, process equipment, other chemicals, engineering controls, frequency of exposure, or work practices. Examples of such changes are shown in Table I. The changes and years were entered into the DEP. Whether this change affected the job's exposure ("applies") and the effect of the change on air concentrations were also identified. Effect was a numeric value from 0.01 to 99.99, reflecting either a positive or negative change in the exposure level. Up to 190 changes could be entered for each department, but seldom were more than 25 entered. The field

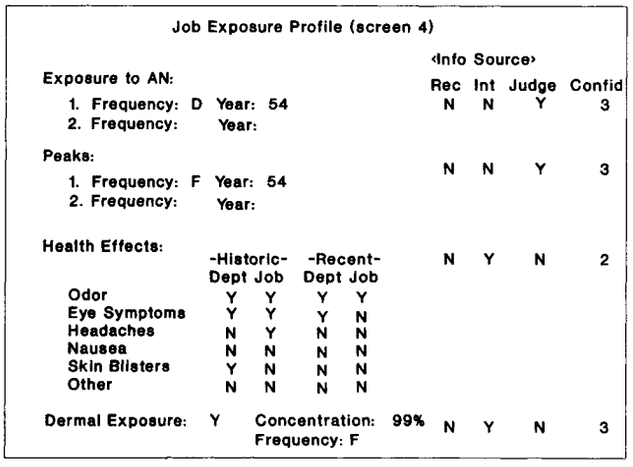

FIGURE 4. Screen 4 identifies the frequency of exposure to a measurable amount of AN (D = daily), the frequency of peak exposures (F = frequent, i.e., daily), reported health effects (yes/no) for the department and the job historically (< 1978) and recently (>1978), and the concentration and frequency (F = frequent, i.e., daily) of dermal exposure. For details on source of information and confidence, see screen 1.

for unusual occurrences permitted entry of a DEP description of any major nonroutine occurrences, such as strikes, shutdowns, explosions, and so on.

Screen 3 (Figure 3)

Production rates of AN or AN product by year and the dates of routine overtime were identified. These were DEP fields.

Screen 4 (Figure 4)

The frequency of exposure, that is, how often the job was exposed to a measurable amount of AN, and frequency of peak exposures (> 20 ppm for at least 15 min were identified. The dates were also provided. Also on this screen, various health effects reported by the interviewees both historically [prior to 1978, the year of the new Occupational Safety and Health Administration (OSHA) standard] or recently (after 1978) were identified either on the department level or specifically for the job. The frequency of dermal exposures in the job and the concentration of AN in the liquid were entered.

Screen 5 (Figure 5)

This screen identified various types of personal protective equipment (PPE) used and the date they became available, the date that use became mandatory, and the date when mandatory use was no longer in effect. PPE use was described both on the department and the job level. Level of physical activity was defined as how active the employee was required to be on the job over the course of the day, based on the tasks performed: heavy (heavy activity, such as digging ditches, etc.), moderate (walking about with moderate lifting or pushing), or light (sitting or standing to control machines, performing light hand or arm work).

Screen 6 (Figure 6)

A ranking by AN exposure (from high to low) of jobs within a department, as reported by the workers during the interviews, was entered on the DEP level. Other major chemicals to which all jobs in the department were exposed from the manufacturing process were identified, as well as chemicals to which only particular jobs were exposed. For information that did not readily fit into any of the above screens, there was a text field for general comments.

Job Exposure Profile (screen 5)

Personal Protective Equipment:		‹Info Source› Rec	Int	Judge	Confid
		N	N	Y	3
	Year Started ‹Optional›	Year Started ‹Mandatory›		Year Stopped ‹Mandatory›	
Gloves, Latex					
Leather	54/98				
Rubber	54/98				
Not Specified					
Safety Glasses, Goggles					
Clothing: Footwear					
Half-Mask					
Full-face Piece					
Supplied Air					
Respirator, NS					
Level of Physical Activity (HML):	M	N	N	Y	3

FIGURE 5. Screen 5 identifies the dates of personal protective use (98 = no information) when it was optional, mandatory, and no longer mandatory, and the level of physical activity (H = high, M = moderate, L = light). For details on source of information and confidence, see screen 1.

Job Exposure Profile (screen 6)

Ranking of Jobs within Department:	‹Info Source› Rec	Int	Judge	Confid
1. Asst purification op				
2. Reactor op	N	Y	N	3
3. Catalyst recovery op				
4. Foreman				
5. Control room op				
Dept Chemicals:	Y	Y	Y	1

Acetylene; Cuprous chloride; HCN; Hydroquinone; Lactonitrile

Job Chemicals:

Dept Comments

PROCESS: At one time had called the dept 2 separate depts. HEALTH: 1.1-8, 101; More people got sick from HCN than AN

FIGURE 6. Screen 6 identifies the ranking of the jobs by exposure level within the department, chemicals to which most of the jobs within the department were exposed, chemicals to which only this particular job was exposed, and general comments. For details on source of information and confidence, see screen 1.

The information allowed by the system was virtually impossible to collect on the several thousand jobs in the study within a reasonable time frame, so that most of the data collected were on the most frequently held jobs. For jobs held by few workers, judgment was often used to support the exposure or job-related information entered and the basis for this judgment was identified. For many of the fields, the judgment applied to each of the jobs within a department was the same. For example, for most of the production jobs, the investigators did not specifically ask how many days a week the jobs were exposed to AN. Rather, because they were normal production jobs, a judgment was made that exposure was daily. To support this judgment, a statement such as "this is a normal production job and therefore it was likely to have daily exposure" was made. To reduce the amount of time spent entering identical information, "general industry practices" (GIP) were developed by the investigators and a code assigned to each practice (see examples in Table II). Continuing with the example, for a production job, rather than entering the judgment described above, only GIP-FR-1 was entered (Table II).

Document Control Notebooks

For each plant a document control notebook was developed to organize the information collected from the plant. This notebook contained all the field notes and reports generated by the study investigators and all the records collected from the companies and unions. The notebook was organized into sections that encompassed the site visits (the final reports, field notes, interview forms, job lists from

TABLE II. General Industry Practices*

Code	General Industry Practice
Location	
LO-1	The job duties were likely to cover all areas of plant
LO-2	The job duties were likely to be limited to office areas
LO-3	This job was mainly outside
Frequency of exposure	
FR-1	The process was likely to run on a daily basis
FR-2	The duties of the job required the employees to regularly get into the plant to check on the process
FR-3	The job did not handle AN

*Examples of comments entered in the judgment field to support descriptive exposure information made on the basis of judgment. The user entered the code to designate the appropriate judgment.

the abstracted personnel records), technical information received from the company (production figures, process flows, water quality analyses, plant layouts, job descriptions, etc), the sampling sheets for the air monitoring conducted by the study investigators, and other miscellaneous information. Each document was identified by a section, a subsection, and a page number. Pagination started anew with each subsection, allowing insertion of additional documents to any section.

Quality Assurance

The system was developed with several quality control checks. Every field of each profile identified the page number of the document where the information was found, or if a judgment was made, the basis of that judgment. This documentation is easily retrievable by a second reviewer. Also, there were several internal logic and range checks in the system. For example, the system would not allow entry of years in the frequency of exposure field outside the years the job or department was in existence. In addition, edit reports were developed to identify inconsistencies, such as the presence of peak exposures when frequency of exposure was none. A user's manual was developed that described, step by step, use of the JEP system, including completion and examples of the screens, purpose of the logic checks, and generation of the edit reports. Each profile was reviewed by a second industrial hygienist familiar with the plant.

Discussion

The advantage of having a computerized system is that it organizes and documents in an efficient way the large amounts of data collected in industry-based epidemiologic studies. This characteristic is particularly important because exposure information may come from many different sources and a single document may contain references to several departments or jobs. For example, each document control notebook for the eight plants in this study contained over 400 pages. Developing a paper copy form for each job would allow compilation of the exposure information, but it would result in much information being repeated in an unmanageable amount of paper. It would also prevent easy reference back to the original document. For these reasons, a computerized data management information system was developed for this study.

The methodology developed for this system is adaptable to other studies. It addresses the basic components of exposure and, further, provides a structure that indicates what information should be collected during site visits to companies under study. It was developed for the information collected in this study; but changes in the data collection (and therefore the system) can be made in future studies. For example, although the system allows identification of confounding exposures, it records detailed information on only a single exposure. We are currently in the process of modifying the program to allow for assessment of multiple exposures.

Although designed as a tool to manage a data base for reconstruction of historical exposures, the JEP system could be used in the workplace to collect and maintain exposure information. An annual evaluation of all jobs in such a format would be a valuable resource for investigators performing exposure assessments both currently and in the future. The system could also be used to simply document descriptive information collected on jobs or departments in an epidemiologic study by itself, or it could be used to develop exposure estimates using assessment methods developed by the user. The latter would, of course, require development of an exposure assessment program by the investigator, but the data could be compatible with other systems.

This system is the first computerized program developed for the exposure assessment part of this epidemiologic study. A second system, the linkage system, links the job and department titles in the personnel records to the job and department titles in the air monitoring records. After computerizing the air monitoring data, a third system, the exposure assessment program (EAP), interacts with the first two systems to develop exposure estimates. The EAP system links the monitoring data with the JEP/DEP information and guides the user through a step-by-step process to develop the exposure estimates for every job in the study. This system has been completed and is being used by the investigators. The EAP and the second system will be described in a future report. The JEP/DEP system and the accompanying user's manual are currently being developed for use by the public. For more information on the system's hardware and software requirements, see the Appendix. For more information on the availability of the system, contact should be made to the first author.

Disclaimer

Mention of any product or manufacturer does not constitute endorsement by either the National Cancer Institute or the National Institute for Occupational Safety and Health.

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Appendix

This system was developed by using the relational database management system (RDBMS) software package Clipper® from the Nantucket Corporation. The programs are fully compiled so that Clipper is not required in order to run the system. The current version of the system can run on any 286, 386, or 486 type PC compatible that runs at least DOS version 3.31 and has 640K of memory. A color monitor is desirable, but not required. The current version of the system is very easy to install and maintain and only minimal support from a midlevel programmer is required. However, the files created by the system are hierarchical Clipper data bases that must be accessed by an experienced Clipper programmer. It is possible to produce flat ASCII files; however, processing these files with their complicated hierarchical relationships still requires an experienced programmer. If the system is used only to record and review information and to produce the standard reports supported by the system, such access is not required and minimal support should be sufficient.