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Conference on Occupational Exposure Databases: A Report and Look at the Future

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The rationale, goals, and interdisciplinary and multi-institutional character of the Conference on Occupational Exposure Databases are described based on a conceptual framework for thinking about exposure data. The three areas that pose the critical challenges to database developments are discussed 1) the multiple and changing uses and users of data; 2) the need for better and *standardized* definitions of the exposure-relevant information which should be collected along with exposure measurements; and 3) the closely related and equally critical coding issues. The concluding section summarizes the principal consensus views and recommendations from the conference and the status of the activities now underway to implement those recommendations. GÓMEZ, M.R.; RAWLS, G. CONFERENCE ON OCCUPATIONAL EXPOSURE DATABASES: A REPORT AND LOOK AT THE FUTURE. APPL. OCCUP. ENVIRON. HYG. 10(4):238–243; 1995.

The decision to organize the Conference on Occupational Exposure Databases was based on *two* deceptively simple premises. First, the nation pays dearly to collect thousands of workplace exposure samples every day, yet we badly fail to exploit the full potential of much of these data. Second, the increasing need for more sophisticated exposure assessments(' ') and the availability of new technologies in sampling, analysis and data management virtually demand qualitative advances in the way we collect, store, use, and share our exposure data in the 21st Century.

Many millions of dollars are spent every year to measure exposures to workplace hazards, compare the results to permissible levels, and take protective measures when necessary. These measurements are collected in the frontlines of industrial hygiene, for use in very immediate and local contexts, and thus they play an undeniably critical role in the protection of workers. Records of these measurements are often stored for legal and administrative reasons following their compliance-related uses but. unfortunately, they ***are rarely used again.*** Yet it is clear that large repositories of stored measurements, or databases, could and should play a far greater role than they do today in practically every stage of the assessment and management of workplace risks, beyond their traditional compliance roles. Briefly, occupational exposure databases can:

- help evaluate the success or failure of risk management activities by establishing baseline exposure levels for different groups or populations and then obsen ing trends in those levels following regulations, corporate policies, inspection strategies, training efforts, or other risk management steps;
- accomplish hazard surveillance functions to identify high exposure/high risk groups *before* disease occurs, as well as *low* exposure groups to be used as benchmarks for reducing exposures;
- support epidemic ;ic research to identify hazardous substances and/or establish exposure-response relationships;
- help to develop a better understanding of exposure determinants, or the circumstances that give rise to exposures, through modeling research; and
- better inform regulatory decisions by supporting population exposure assessments, regulatory cost estimates, and other aspects of regulatory analysis.

Based on the sizable untapped potential of exposure databases in these areas, the goals of the conference were to:

1. review the state of the art in occupational exposure databases through the examination of currently available &@- bases, their contents, organization, strengths, and limitations;
2. seek ways to ***optimize*** the use of existing databases; and
3. stimulate the development of ***consensus recommendations*** for the future collection, abstraction, coding, storage, access, and analysis of exposure data in such databases.

The idea for the Conference was born in the Computer Committee of the ACGIH. From the beginning, the planning took a very broad view of exposure database issues, emphasizing their role as a multifaceted tool in the assessment and management of workplace hazards. M e r obtaining early co-sponsorship fiom the AIHA, the planning discussions spread to numerous other technical committees of both associations. The collaboration was substantial and very productive. The Department of Energy was an early and enthusiastic supporter, as was NIOSH at a later stage.

We explicitly sought and successfully obtained the participation of a broad range of institutions fiom the public, private, and international sectors, as well as a wide spectrum of scientific and professional disciplines interested in database applications. The reasons for this multidisciplinary and multi-institutional emphasis were also conceptually simple: If exposure databases are to prove effective, they must be able to serve many different needs. Judging from the participants in the conference, these goals were accomplished. The participants included backgrounds in industrial hygiene, epidemiology, policy analysis, regulation, modeling, occupational health management, medicine, law, and computer systems. We were also fortunate to have participants from Britain, Canada, Denmark, and France. The turnout for the conference was three

Preface

The Worlds of Occupational Exposure Databases

Greg Rawls, Cu-Chair, Occupational Exposure Database Conference

Sometime during our adolescence, we all had the opportunity to read *The Hobbit* by J.R.R. Tolkien. I'd like to take some liberties and tell you my version of this story.

This is a story of the three different worlds of occupational exposure data. Each world is important and dependent upon the others, even though they don't always realize it. People inhabiting these worlds have work to do and have often developed very complicated, intricate, and individualized ways of doing their tasks. The people of these three worlds have obligations to each other, but all are very busy within their own world, and communication to the outside is limited and often very frustrating.

Let me tell you about these three worlds:

The *Inner World* is where the data are collected, modified, and analyzed to service immediate needs. It is a world inhabited by *Data Owners*, most of whom are industrial hygienists. Acquisition of data is driven by the desire for compliance and the need to determine employee protection and engineering controls. By the nature of their work, their focus is concentrated in a small area. Data usefulness is limited by systems developed by and for the Data Owners to meet immediate needs, with little thought to anything outside the Inner World. There is little consistency among the data collected in the Inner World, but this is not important since within this world there is little need for data exchange. Data Owners are not &ish—they are usually happy to share their data but they lack the means to do this effectively. *So* what is the probability that the Data Owners are making provisions for data to be useful to anyone but themselves? This is not a problem for Data Owners but is a problem for the other worlds.

The *Middle World* is the next level and includes corporate headquarters, specific industries, an EPA or OSHA region, or some larger group made up of one to several Inner Worlds. People in the Middle World are *Data Borrowers* and are usually managers. They need data to compile reports, determine productivity, and set policy. Their focus is larger and considers the needs of more people. The Middle World often directs data collection in the Inner World, which is sometimes seen as an interference. Once data reach this level, they become less useful because people in the Inner World are very busy and have little time to consider the needs of those in the Middle World. There is still some degree of ownership, but usefulness becomes vague.

Finally, we come to the *Outer World* which includes all the Middle Worlds. This world is made up of everyone who wants and needs access to data from the Inner World. This is a world inhabited by *Data Wanters* who are usually epidemiologists and standard setters. Unfortunately, by the time this level is reached, the data are obscure, vague, poorly supported, and of little use. Information that was readily understood by the Data Owners raises questions of validity to the Data Wanters.

So what can be done to make data collected in the Inner World useful to all other worlds? This conference was a start. And unlike most conferences, there was nothing passive about this gathering, Active participation was required. Representatives of the three worlds—Data Owners, Data Borrowers, and Data Wanters—were in attendance. The conference provided the opportunity to talk to each other and determine what they have in common. Ideas were exchanged about what is important for an occupational exposure database, weeding out the trivial and concentrating on the important. We wanted occupational exposure data to have value, to have usefulness that expands beyond the confines of just one world. Participants were encouraged to listen to the papers and talk to the authors. In particular, the workshops provided an excellent opportunity to come to some conclusions and maybe even a consensus about what was important.

This conference was the first, and hopefully not the last, of its kind. There were representatives from 33 states and 9 countries. Important interchanges took place. Even though we came fiom the different worlds, we had a common goal—to make occupational exposure databases useful to all worlds.

times what was originally anticipated, confirming our suspicion that the time was right to initiate a careful examination of database experiences and future perspectives.

The proceedings in this volume contain the technical and roundtable presentations from the conference, and summaries of the reports from the workshops. We believe that they reflect the current state of the science in databases today, and that they pose a challenging mix of opportunities and difficulties in the effort to qualitatively improve the use of our exposure measurements.

The remainder of this article weaves our own thoughts, as we expressed them during the conference, with our reflections since that time, enriched by a careful reading of the papers. The first section describes a conceptual framework for thinking about exposure data. The second section focuses on three areas that pose the critical challenges to database developments: 1) the multiple and changing uses and users of data; 2) the need for better and *standardized* definitions of the exposure-relevant information which should be collected along with exposure measurements; and 3) the closely related and equally critical coding issues. In the concluding section we summarize the principal consensus views and recommendations from the conference and briefly describe the status of the activities now underway to implement those recommendations.

The Worlds of Exposure Data

In his opening remarks to the conference, Greg Rawls proposed a conceptual framework, loosely borrowed fiom J.R.R. Tolkien's *The Hobbit*, to identify and understand the challenges that we face in optimizing the use of our exposure data. In this imaginary scheme, three "worlds" of occupational data exist, which are described below. Each world has its own inhabitants, its own relationship with the data, and its own set of rules. The worlds are related through mutual obligations, but their inhabitants are all very busy within their own worlds and communications among them are limited and often frustrating. The relationships between them and their data needs are changing rapidly as a result of new paradigms for exposure assessment which are rapidly coming into their own.[1–5] Understanding these changes is necessary to be able to improve the databases of the next century.

The Inner World is where the data are collected to service immediate needs. It is a world inhabited by *Data Owners*, typically industrial hygienists. They are driven by a desire for compliance and the need to determine employee protection, and currently there is little incentive or probability that they will make provisions for their data to be useful to anyone outside their world. Their focus is by necessity concentrated in small areas. Data usefulness is defined by criteria developed by and for the Data Owners to meet immediate needs. Many of the participants in the conference had extensive experience in this Inner World early in their careers, but are now active in the other worlds, or at least aware of their needs.

The Middle World is the next level, which is inhabited by *Data Borrowers*. It includes corporate headquarters, specific industries, trade unions, trade associations, federal regions, individual federal or state agencies or other such groups, each made up of one to several Inner Worlds. The inhabitants are usually middle managers who need data to compile administrative reports, measure productivity, and set operational policies. Their focus is larger than that of the Inner World but largely administrative. They do not generate data but often influence or even direct the data collection in the Inner World, which may perceive their influence as needless interference. Many of the presentations describing the databases of large corporations and the armed services[6–8] during the conference were designed with the perspectives of this Middle World in mind.

The final level is the Outer World, which includes all the Middle Worlds. This world includes everyone who wants and needs access to large volumes of data from the Inner and Middle Worlds. This world is inhabited by ***Data Wanters*** who are standard setters, risk analysts, epidemiologists, and the like. They also analyze the data to compile reports and set policy, but at a much broader level than the Middle World. Unfortunately, by the time exposure data from the Inner World reaches this level it is often of poor quality or inappropriatefor ***their needs.*** Information that was readily understood and useful to the Data Owners, and largely to the Data Borrowers, has been lost or is not appropriate to the needs of the Data Wanters. There are also conflicts that hamper the transfer of data to this Outer World. At times, the traditional data "owners" in the Inner World would be happy to share their data but they lack the means to do so effectively. At other times, however, a variety of conflicts with the Middle and Outer Worlds about access to the data can arise and elicit thorny questions regarding privacy, proprietary claims, liability risks, right-to-know, public health, and equity concerns.

The purposes of the conference can be seen in terms of this framework. The evolution of qualitatively new concepts and approaches in exposure assessment increasingly require "new" forms of exposure data and "new" ways to use them.[1–5] These changes, in turn, profoundly impact the relationships between the three worlds of data, in both positive and potentially negative ways. New requirements for data by the Outer World make increasing demands on the Inner and Middle Worlds. On the other hand, the new uses of these data also rebound, or *should* rebound, to the benefit of the inner worlds by helping to identify new hazards that must be monitored, by better focusing regulatory requirements, etc. These benefits are long term and indirect, however, while the obstacles are more immediate. In part because of these reasons, the three worlds are today quite apart in the manner in which they define the data that are needed to further their common purpose of protecting workers. The conference, therefore, was also an effort to better understand these different worlds, to better coordinate their needs and activities, and thus to optimize the usefulness of our exposure data resources, and especially our databases, in the future.

Critical Challenges for Database Improvements

Databases Users *and Uses*

Exposure data are essential at every stage of risk assessment and risk management for workplace hazards, and exposure databases are increasingly important tools to carry out these activities. The most prominent use of exposure data in the past has been to address the everyday affairs of compliance with exposure standards, which are primarily activities of the Inner and Middle Worlds. In addition to these compliance-related ob-

jectives, exposure data can and should support a wide range of activities in the Outer World, as described earlier. Until recently, the Inner and Middle Worlds have had little reason to generate data in a manner that would be applicable to such database uses in the Outer World.

The practitioners in the Inner, Middle, and Outer Worlds do not pose identical questions of exposure data, and thus they look at their data needs from different perspectives. The conference was rich with examples of this diversity of potential database uses. In his opening address, Lippmann[9] developed many of the conceptual requirements for multiple database uses, based on a review of much of the recently reported experience with *environmental* databases (e.g., ambient air, water, etc.). Harris[10] described minimum criteria for data that may eventually be needed for epidemiologic study, which he developed for the Chemical Manufacturers Association. Greife *et al.*[11] described the NIOSH general industry databases. Begin *et al.*[12] described the successful extraction of exposure data fiom old inspection records to form a database in support of epidemiologic research. Botkin and Conway[13] fiom the OSHA Office of Policy, made a strong argument in favor of a national exposure databank and other improved database resources to support regulatory analysis. Weeks,[14] on the other hand, warned about the serious problems encountered with allegedly fiaudulent data in a large database in the mining industry. Lubek[15] provided a successful example of a regulatory agency database in a Canadian province that is being effectively used for multiple purposes, including the planning of inspection activities. Jayjock and Hawkins,[16] Knechtges,[17] and Fehrenbacher[18] addressed the use of databases in the development and validation of exposure models. Finally, Mirer[19] stressed the need to develop databases that can help identify the *lowest* exposures achievable in a process or industry, and the conditions that account for them, as benchmarks for others and for the regulatory process.

Numerous presentations also illustrated the kinds of conflicts about access to data that can arise between the different worlds. For example, the pesticide exposure database described by Leighton *et al.*[20] developed by EPA, Health Canada, and the National Agricultural Chemicals Association does not contain the names of specific chemicals (or companies), but simply generic identification and physical and chemical properties. This is a result of the confidential nature of the data from which the database is drawn. Ashford[21] raised important ethical and legal questions regarding access *to* exposure data by different parties, and Railton[22] described some of the liability concerns that may face everyone from the Data Owners to the Data Wanters.

Exposure *Determinant and Coding Issues*

Exposure measurements alone are relatively meaningless numbers, unless they are accompanied by information about *exposure determinants*, defined as variables that describe "the circumstances that gave rise to the measured exposures."[23] Information about such exposure-relevant variables is indispensable for the interpretation of raw measurements, because it permits their stratification into groups or categories that are meaningful for inferential analysis, such as homogeneous exposure groups.[1,23–26] One of the main reasons we fail to exploit the full potential of the exposure data we collect is that we do a rather poor job of collecting information about such exposure determinants in our databases. This is primarily because we have no consensus regardmg: (1) the choice of determinants that we should collect information about; (2) accurate and standardized definitions for those determinants which we agree are needed; or (3) coding systems which can effectively capture information about most of these detemiinants.

For example, nearly everyone would agree that the type of industry in which a measurement was taken is an important factor to record for large database purposes. But to what degree of specificity is industry to be defined? Is the level of specificity of a four-digit Standard Industrial Classification code sufficient? If not, is it worthwhile to use the more detailed seven-digit system which is available for manufacturing industries, as has been suggested?[27] Neither system is designed for exposure purposes, but the latter can certainly capture more exposure-relevant information than the former.[27] Moreover, how should industry identification be captured for large establishments that may have multiple facilities, each perhaps with a distinct "industry" character (i.e., a combined mine, mill, smelter, and refinery)?

In the same vein, should our databases contain information about process and operation? Are not these variables potentially important determinants of exposure, as well as useful for proper aggregation of data for analysis? In his paper, Damiano[28] describes a fair degree of specificity in capturing process and operation data, and discusses some of the difficulties in doing so. Trawick[29] also addresses these factors in his description of a corporate database. These approaches are, however, very company- and industry-specific. Can the principles underlying them be adapted for generic application for larger databases? Even if we answer yes to these questions, there are no currently available coding systems to capture such data in a standardized or systematic fashion.

There is also widespread agreement that information about job title must accompany any measurement if it is to be at all useful in a database. Traditional job titles of the kind retained by personnel or payroll records are certainly not the way, yet it is not clear *how* we can best capture such information in *an* exposure-relevant manner. The job titles used in the mining industry appear to effectively capture such exposure-relevant information in a comprehensive manner and may offer clues applicable to other industries.[30,31]

Moreover, should our databases also extend beyond "good" job titles to also include job task information? If so, how? In their paper, Susie and Schneider[32] emphasized the need for task-based databases in the construction industry, given the rapidly changing job environments in that industry, as opposed to the more typical manufacturing workplaces. It is not clear, however, how or whether their coding approaches could be made applicable to manufacturing and/or service industries or compatible with existing systems. Burr[33] also described an intriguing conceptual rationale being developed in the Netherlands for describing and coding work process data. Its practical applicability to the U.S. reality appears to be well worth examining. Finally, existing coding systems, such as the Standard Occupational Classifications or the Bureau of the Census, as Nelson[34] pointed out, are hardly designed for exposure assessment purposes. The *Dictionary of Occupational Titles*, which is available for use in easily searchable computerized form, may

offer advantages in this area, however, because it is able to capture exposure-relevant information about industry, job, *and* task, but it is a complex system which may prove costly to use and which has not been widely tested in occupational database applications.

The examples of industry, process, operation, job, and task are important but not the only examples of exposure determinants whose roles in databases and exposure assessment need to be more accurately defined. Other variables have been described in the literature that may need to be included in the list of important exposure determinants for databases. For example, a partial list might include work practices, process equipment and conditions, exposure controls in use, the year and season, the reasons for the measurements and the sampling strategy(ies) employed in their collection.[1,23,33–41] Indeed, the need for additional information about exposure determinants in our databases was reflected in all the large systems that were described at the conference. For example, Beaumont[42] described the process and rationale that led to a British consensus standard for exposure database contents. Their list of determinants is a compromise between the need for determinant information and the practical and cost limits to data collection and storage. Lubek,[15] fiom Ontario, Canada, described a similar approach for their database. Several of the private sector databases captured more information than these public systems, but with Middle World approaches specific to their industries or companies.[43,44] It is not clear, however, how or whether these approaches can be adapted to Outer World uses.

Finally, it is essential to explicitly stress the issue of coding. All the potential uses of large databases described earlier demand that the information accompanying the large numbers of exposure measurements be amenable to statistical analysis. Standardized definitions for databases *in the form of codes* are necessary to accomplish this goal. For large database purposes, it is not sufficient to select and define consensus exposure determinants. The closely related but distinct issues of coding will need to be addressed by selecting or developing appropriate coding systems for all the standardized database variables.(".&)

Conclusions and Future Steps

The conference brought together a wealth of experience regarding the issues summarized above, as well as many other issues that can be found in the individual papers. As in any conference, the resulting dialogue answered a few questions but also raised many new ones. Also, the conference can make no claim to represent a formal consensus process regarding database issues, although it served as a forum for a very rich exchange of ideas. We are comfortable in asserting, however, that consensus among the participants was palpable on five key issues.

1. *The time is ripe for progress in database design and use.* The conflurnce of new paradigms for exposure assessment, new needs, and the availability of new tools present exciting new opportunities and virtually *demand* that we design and implement qualitatively new databases to serve us in the 21st Century.
2. *Progress in databases must incorporate and reflect the needs of multiple users and uses.* In terms of the three data "worlds," this view demands that the relationships between those worlds be redefined and that numerous disciplines and their perspectives have a direct hand in designing and implementing the databases of the future.
3. *There is a need to identify and define the key data elements for our databases in a uniform and standardized manner.* We don't know or don't agree on what exposure determinants we need to collect along with our exposure measurements. Even when we do agree on specific factors or determinants, we often do not agree on their precise definitions or how best to capture them for our "new" purposes. We need to come to such agreements and consensus definitions.
4. *There is a need to adopt, adapt, or develop uniform or at least compatible coding systems to record the variables in our databases.* The very purposes of large databases, the "new" uses of data described earlier, require that measurement results and the accompanying determinants be amenable to statistical analysis. Codes are essential to accomplish this, and coding systems absolutely *must be* uniform or compatible across institutions so that data sources can be merged for different uses as needed.
5. *The window of opportunity is now.* During the conference, we saw a tremendous explosion in database design and implementation occurring in the private and public sectors today. This is very exciting and encouraging, but it also presents some very real dangers. If we are not careful, we could be saddled with a multitude of database systems, some good and some not so good, but all *different and incompatible,* in the very near future. That is why the conference concluded that we have a window of opportunity *now,* an opportunity for coordinated development of consensus approaches to databases, before the concrete sets on many individual systems and they are too entrenched to move to common ground.

In concrete terms, the conference resulted in the creation of a Joint Workgroup on Occupational Exposure Databases, with the support of the Boards of both societies. The group is chaired by Dr. Mort Lippmann, of New York University, vice-chaired by the authors, and composed of four members each fiom ACGIH and AIHA. For the last several months, the workgroup has been dealing with: (1) a better understanding of the different users and uses of databases; (2) developing a first draft of a list of key database variables and their definitions; (3) addressing coding needs; and (4) defining what the obstacles are to coordinated improvements in databases.

At the AIHCE in Anaheim, California, the workgroup reported on its progress to the Boards of both associations and presented a very concrete plan of action for the next year. The response of both Boards continues to be supportive of the basic aspects of what was proposed, and the work of the joint workgroup will go forward.

The workgroup will finalize what is now a draft list of key data elements for occupational exposure databases. This draft list will include definitions and a rationale for those data elements and a number of other explanatory components. The draft list will undergo a round of peer reviews by both technical experts and stakeholders. With the draft list completed and serving as a guiding document, the workgroup will then

collect and critically analyze existing coding systems that may serve to code these key data elements. A technical workshop on coding issues will be held in early 1995 to examine and select from different coding options for the full list of data elements.

Following the workshop, the workgroup will develop a report with specific *recommendations* regarding key data elements, coding approaches and needs, and future steps. This document will undergo extensive peer review by technical experts and stakeholders in 1995. A final draft is expected to be available in late 1995. At next year's AIHCE, a roundtable and other activities will contribute to these plans. Finally, throughout this process, an outreach subgroup of the workgroup will work to engage all the different sectors with a stake in the development of this work to identify obstacles and pitfalls in the real world and to try to address them.

We are confident that these workgroup activities will result in a consensus document that will address the two most urgent needs in the database arena today: definition of key data elements and many coding issues. But the process must not end there. The conference also raised many other questions that will require answers in the near future. For example, there will be a need to develop incentives for data collectors and upper management to adopt the consensus recommendations. As the recommendations are implemented, it will be necessary to have in place systems that assure minimal quality of stored data, so that future merged uses of it can yield reliable results. Also, the creation of large exposure databases in standardized formats will make their contents more susceptible and attractive to requests for access by parties other than the original collectors. This will result in increased clashes between the concerns for confidentiality and the right to know, and possibly liability and other legal disputes. The proposal for a National Occupational Exposure Databank is likely to receive increased attention.[46] The need to capture in our databases observations and decisions from the initial (and qualitative) exposure characterization of exposure assessments, which was a topic of several conference speakers, will also come to the fore. Finally, and perhaps most important, exposure databases must be adaptable to the inevitable changes in our knowledge of what data are important to keep and in what form, to the emergence of new industries, jobs, and hazards, and to the necessary updating of coding systems. For these and many other reasons which we cannot mention in the space of this article, the process initiated with this conference must continue.

In the final analysis, the common purpose of our three fictional data worlds, and of all database uses and users, is the protection of workers. Although there is no easy road ahead for database progress, the potential of these instruments to advance this common purpose in the 21st Century is enormous. We believe that the Conference, these proceedings, and the continuing activities of the joint workgroup are important steps in this direction, and we urge all the members of the industrial hygiene profession to join in this effort.

Disclaimer

This manuscript represents the views of the authors. It has not been subject to review by the Environmental Protection Agency, and does not represent its views.

References

1. Hawkins, N.C.; Norwood, S.K.; Rock, J.C. (Eds.): A Strategy for Occupational Exposure Assessment. American Industrial Hygene Association, Fairfax, VA (1991).
2. Hawkins, N.C.: A Rationale and Framework for Establishing the Quality of Human Exposure Assessments. Am. Ind. Hyg. Assoc. J. 53(1):34–41 (1992).
3. Hams, R.: Health Workers, A Professional Foundation, and Great Opportunities. Cummings Award Lecture. Am. Ind. Hyg. Assoc. J. (in print).
4. Burdoff, A.: Shifting Concepts in Assessment of occupational Exposures. Ann. Occup. Hyg. 37:447–450 (1993).
5. Tait, K.: The Critical Role of Qualitative Exposure Assessment: The Workplace Exposure Assessment Database (WORKBASE).
6. Morgan, D.A.: U.S. Army Occupational Health Management Information Systems (OHMIS). Health Hazard Information Module Version 2.2 (HHIM).
7. Randolph, B.L.: Application Development of the Integrated Network for Safety, Industrial Hygiene, Health and Training (INSIHT).
8. Smith, T.; Floree, C.: An Occupational Exposure Database—The Idaho National Engineering Laboratory.
9. Lippmann, M.L.: Exposure Data Needs in Risk Assessment and Risk Management: Database Information Needs.
10. Hams, R.L.: Guideline for Collection of Industrial Hygiene Exposure Data for Epidemiologic Use.
11. Greife, A.; Young, R.; Carroll, W.; et al.: The NIOSH General Industry Occupational Exposure Databases: Their Capabilities and Limitations.
12. Begin, D.; Gerin, M.; Adib G.; et al.: Development of an Occupational Exposure Data Bank on the Territory of a Department of Community Health in Montreal.
13. Botkin, A.; Conway, H.: The Relevance of Exposure Data to Regulatory Impact Analyses: Overcoming Availability Problems.
14. Weeks, J.L.: Uses and Abuses of Exposure Monitoring in Coal Mines.
15. Lubek, B.M.: The Province of Ontario Medical Surveillance Database.
16. Jayjock, M.A.; Hawkins, N.C.: Exposure Database Improvements for Indoor Air Model Validation.
17. Knechtges, P.L.: A Knowledge-Eased Approach to Using Databases for Occupational Exposure Assessment.
18. Fehrenbacher, M.C.: EPA's Use of Occupational Exposure Databases for Screening Level Assessments Under TSCA.
19. Mirer, F.L.: Occupational Exposure Databases: Limitations on Retrospective Exposure Determinations, Prospects for Future Control of Exposures.
20. Leighton, T.M.; Neilsen, A.P.: The U.S. EPA, Health Canada, and National Agricultural Chemical Association's Pesticide Hander's Exposure Database (PHED).
21. Ashford, N.: Presentation at Legal and Regulatory Roundtable.
22. Railton, W.S.: Management Safety and Health Data and OSHA.
23. Beaumont, P.L.; Dalrymple, H.L.: A Standard for the Presentation of Occupational Exposure Data. Ann. Occup. Hyg. 36(1): 79–98 (1992).
24. Rappaport, S.M.: Assessment of Long-Term Exposures to Toxic Substances in Air. Ann. Occup. Hyg. 35:61–121 (1991).
25. Esmen, N.A.: Retrospective Industrial Hygiene Surveys. Am. Ind. Hyg. Assoc. J. 40:58–65 (1979).
26. Corn, M.; Esmen, N.: workplace Exposure Zones for Classification of Employee Exposures to Physical and Chemical Agents. Am. Ind. Hyg. Assoc. J. 40:47–57 (1979).
27. Gomez, M.R.: Recommendations for Methods to Code Industry and Job Task in Routinely-Collected Exposure Data. Am. Ind. Hyg. Assoc. J. 55(8):743–747 (1994).

28. Damiano, J.: Quantitative Exposure Assessment Strategies and Data at ALCOA.
29. Trawick, E.: Development of a Statistically Based Computerized Industrial Hygiene Monitoring Strategy Program.
30. Watts, W.F.; Parker, D.R.: Mine Inspection Data Analysis System.
31. Roman, J.M.; Groce, D.W.; Hearl, FJ.: National Occupational Health Survey of Mining.
32 Susie, P.; Schneider, S.: Database Needs for a Task-Based Exposure Assessment Model for Construction.
33. Burr, H.: Presentation of a Work Process Code that Enables Data Analysis Pooling Different Types of Knowledge.
34. Nelson, D.I.; Nelson, R.Y.; Hart, K.J.; Asal, N.R.: Hydrocarbon Exposure Assessment Methodology for an Epidemiologic Study of Renal Disease.
35. Greife, A.; Homung, R.W.; Stayner, L.G.; et al.: Development of a Model for Use in Estimating Exposure to Ethylene Oxide in a Retrospective Cohort Mortality Study. Scand. J. Work. Environ. Health 14(Suppl. 1):29–30 (1988).
36. Schneider, T.; Olsen. I.; Jorgensen, O.; Lauenen, B.: Evaluation of Exposure Information. Appl. Occup. Environ. Hyg. 6(6):475–481 (1991).
37. Froines, J.R.; Dellenbaugh, C.A.; Wegman, D.H.: Occupational Health Surveillance: A Means to Identify Work-Related Risks. Am. J. Pub. Health 761089–1096 (1991).
38. U.S. Environmental Protection Agency: Guidelines for Statistical Analysis of Occupational Exposure Data. Draft Final. U.S. EPA, Office of Pesticides and Toxic Substances, Washington, DC (1989).
39. Office of Technology Assessment: An Analysis of OSHA Health Inspection Data, by J. Mendeloff [Working document] Washington, D.C.: U.S. Congress, Office of Technology Assessment (1983).
40. Ulfvarson, U.: Limitations on the Use of Employee Exposure Data on Air Contaminants in Epidemiologic Studies. Int. Arch. Occup. Environ. Health 52:285–300 (1983).
41. Kromhout, H.; Symanski, E.; Rappaport, S.M.: A Comprehensive Evaluation of Within- and Between-Worker Components of Occupational Exposure to Chemical Agents. Ann. Occup. Hyg. 37:253–270 (1993).
42. Beaumont, P.: The British Experience with Occupational Exposure Databases.
43. James, R.R. An Organization Structured Sound Exposure Risk Assessment Database.
44. Sherril, J.: Comprehensive Industrial Hygiene Tracking System.
45. Wrench, C.: Why Standardize Industrial Hygiene Data?
46. Gomez, M.R.: A Proposal To Develop a National Occupational Exposure Databank. Appl. Occup. Environ. Hyg 8(9):768–774 (1993).