Industrial Crisis

Bhopal. Anatomy of a Crisis. PAUL SHRIVASTAVA. Ballinger, Cambridge, MA, 1987. xvi, 185 pp., illus. $19.95. Ballinger Series in Business in a Global Environment.

3 December 1984. Cries of "Run!" "Gas!" "Death!" awakened Ganga Bai. Fleeing a "slum hut," she carried her two-year-old daughter several miles past "death in its most bizarre forms. . . . She thought she had escaped death. But actually she had been carrying it in her arms all along. She looked down into the glazed, open eyes of her still daughter and fell unconscious" (pp. 1–2). The horrendous effects of the leak of methyl isocyanate gas (MIC) from the Union Carbide India Limited pesticide plant in Bhopal were beginning to emerge.

The MIC leak at Bhopal has been called the worst industrial accident in history. Estimates of human casualties vary: government and corporate figures suggest 1,700 deaths; activist and public sources suggest up to 10,000 deaths and 300,000 injuries. And the crisis initiated by the leak continues, according to Shrivastava. Victims have received little compensation, legal battles still rage, and conditions exist for other major industrial accidents. "These crises are universal" (p. xv), and long-term solutions are urgently needed.

The book describes and analyzes the Bhopal accident from a managerial perspective, using the case to establish a conceptual framework for understanding industrial crises. The book is well written and accessible and serves as an excellent introduction to industrial crisis management. Thick descriptions of the events at Bhopal maintain the pace of the book. And the conceptual analysis elucidates social factors that seldom are, but should be, integrated into analyses of risks and impacts of hazardous chemicals.

The book establishes that "there is nothing natural about industrial crises" (p. xvi); they are socially constructed and produced and emerge as the result of political choices. The technology that failed was produced by humans, and the transformation of the leak into a crisis involved interactions among the technological failures and other human and organizational factors.

Accidents are distinguished from crises; crises emerge when events and actions interact unpredictably to threaten the general social structure. Industrial crises have increased significantly in rate in this century. Triggers of crises include industrial accidents, product injuries, sabotage, and pollution. The triggers themselves are frequently caused by unplanned releases of hazardous substances.

The Bhopal crisis was caused, according to the author, by the interaction of HOT (human, organizational, and technological) factors. Human factors identified include operator and managerial errors, lack of safety training and policies, limited staff size, insufficient information on the hazardousness of MIC, and failure to investigate or appreciate preliminary technological troubles. Organizational factors include pressures on operations and productivity in the plant (at the time of the accident, the unprofitable plant was up for sale), high managerial turnover, and inadequate safety procedures. One technical precondition was problematic plant design. This interacted with other technical problems including water entering the MIC tank and causing a reaction, metallic impurities in the water that accelerated the reaction, and safety devices that were disconnected. These factors were insufficient to cause a large-scale crisis; the environment, a highly populated slum neighborhood surrounding the plant, was crucial, and the location caused thousands of people to be exposed to the toxic gas.

The author describes the divergent views of various stakeholders in the accident (government, Union Carbide, victims) concerning important issues such as types of data that will be accepted, crisis effects, and appropriate responses. These different and highly inconsistent views produced conflicting and contradictory responses to events. The author argues that each group must appreciate the frames of reference of others and must develop an integrated perspective. The utility of a broader perspective can be readily accepted, but the author is perhaps optimistic in implying that this will solve or prevent crises.

Preventing and coping with industrial crises require (i) will to change on the part of stakeholders, (ii) alternative ways of resolving disputes and compensating victims, and (iii) initiatives by each stakeholder, according to the author. The strategies for crisis response that are discussed warrant serious consideration. However, the author argues for public activism to motivate corporate and governmental change. State suppression of public demonstrations by Bhopal victims seeking compensation, as described by the author, clearly indicates the substantial difficulties the public has in pressuring governments and corporations.

This book offers an insightful analysis of the causes and adverse effects of the Bhopal accident and suggests managerial and technological alternatives to present industrial practices. Such analyses and alternatives are necessary if we are to influence the will of organizational elites and encourage more effective management of industrial hazards.

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Radiation Damage: Early Assessments

The Dragon's Tail. Radiation Safety in the Manhattan Project, 1942–1946. BARTON C. HACKER. University of California Press, Berkeley, CA, 1987. x, 259 pp.

The Dragon's Tail is an aptly titled account of an important era in the development of guidelines for protection against ionizing radiation. In the manner of the tale of the Manhattan Engineer District told by Richard Hewlett and Oscar Anderson in *The New World* under the auspices of the Atomic Energy Commission, *The Dragon's Tail* was written under contract with the Nevada Operations Office of the Department of Energy, the successor agency to the AEC. And like *The New World*, this volume is authoritative, scholarly, highly readable, and often spellbinding.

Hacker begins his narrative by summarizing the development up to 1941 of standards for protection for exposure to x-rays and gamma rays, for body levels of radium, and for concentrations of radon. With the organization of the Metallurgical Laboratory and the successful experiment with controlled nuclear fission at the University of Chicago in 1942, a new Health Division was created that laid the groundwork for radiation safety studies in the Manhattan Project. As the bomb program expanded, developing new kinds of production facilities, laboratories, and field tests for the weapon, questions of health and risk in handling operations involving enriched uranium, plutonium, and polonium became the paramount concern of the Health Division. Hacker takes the reader from Chicago to Los Alamos and to the Trinity test at Alamogordo, tracing the basic and applied work of the scientists responsible for safety in the project. There are neither heroes nor villains in Hacker's narrative. Throughout, however, it is made clear that the military aspects of the project always came first, notwithstanding that new knowledge about tolerances and dosages gave grounds for concern.

After Hiroshima and Nagasaki, Manhattan District scientists used the Japanese sites as a source of evidence about the effects of nuclear bomb radiation on humans. The

resulting knowledge was applied quickly in setting safety standards for the conduct of Operation Crossroads, the first postwar series of nuclear weapons tests at Bikini atoll. In Crossroads Test Baker, the second and last shot in the two-bomb series, the scientists for the first time detonated a nuclear device under water. This brought new surprises and concerns even as the completion of the test marked the end of the wartime endeavor. The newly created Atomic Energy Commission replaced the Manhattan Engineer District on 1 January 1947.

Hacker points out the strides made in the field of health physics (the term came from the Health Division of the Met Lab) as a result of the wartime race to build the bomb. Not only did new scientific knowledge emerge, technology was advanced in the development of such items as film badges, pocket dosimeters, and improved radiation counters. Nonetheless, new knowledge based on the experience could not settle the key issue: how much radiation exposure should be allowed a worker or member of the public? In detailing attempts to provide a practical solution Hacker recognizes that the question could not be answered empirically because it included questions of philosophy and public policy. The view that came to prevail was the threshold theory, with its premise that biological systems exposed to radiation below some "tolerance dose" would suffer no lasting effects. Of course, that issue remains debatable.

Unlike the polemical literature currently on the shelves, Hacker's study has successfully sought to reconstruct the World War II era according to its own pattern. That makes it good history. The book also sets the stage for the account of the even more controversial period that will follow in a further volume planned by Hacker.

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Trials and Tabulations

Statistics and the Law. MORRIS H. DEGROOT, STEPHEN E. FIENBERG, and JOSEPH B. KADANE, Eds. Wiley, New York, 1986. xx, 484 pp., illus. $39.95. Wiley Series in Probability and Mathematical Statistics.

Oliver Wendell Holmes wrote in 1897, "For the rational study of the law, the black-letter man may be the man of the present, but the man of the future is the man of statistics and the master of economics." Though his statement is one that the quantitative among us are fond of quoting, one legal scholar has observed wryly that Holmes's prediction might equally well be made today (C. H. Baron, *Am. J. Law Med.* **5** (no. 3), 247 [1979]). We still await a world where lawyers and judges are skilled in the analysis and interpretation of data.

This state of affairs is not due to any lack of relevance of statistics to the law in carrying out its dual tasks: to find facts in particular disputed cases and to set optimal policy, both under conditions of uncertainty. *Statistics and the Law* concentrates on the former, which the law terms adjudicative fact-finding. (Where statistical studies are used to inform policy-making, the law is engaged in the finding of "legislative facts.") Sometimes statistics is not merely relevant but essential for such fact-finding. Some illegal acts, such as employment discrimination or price fixing, normally cannot be perceived except through inferences drawn from statistical information. Individual acts of hiring cannot be in themselves observably discriminatory; only a pattern of hirings statistically analyzed is likely to be able to reveal what the law wants to know.

Statistics and the Law takes an unusual route to the Holmesian future. There are a number of books on law and statistics that are aimed at raising the statistical consciousness of legal people (for example, Baldus and Cole's *Statistical Proof of Discrimination* [Shepard's, 1980]; Barnes's *Statistics as Proof* [Little Brown, 1983]; and Finkelstein's *Quantitative Methods in Law* [Free Press, 1978]). *Statistics and the Law*, by contrast, is "by statisticians for statisticians." It presents a sampling of statistical applications to legal issues written, for the most part, by statisticians who served as expert witnesses in the cases about which they write. The book's purpose is to provide statisticians with examples of the kinds of legal questions that in recent years have invited statistical answers and, perhaps equally important, to introduce them to "the fundamental difference in outlook between lawyers and statisticians" and the challenge of presenting statistical information in a courtroom.

Statistical analysis can inform a broad range of legal matters, from the relatively esoteric where it is most often found today to the mundane tort and contract cases where it may be found tomorrow. The legal topics examined in this book include several aspects of employment discrimination, antitrust litigation, educational equity, and environmental regulation—areas where statisticians already are familiar figures. In addition, there are accounts of the application of statistical methods to more novel problems such as estimating the value of equipment damaged in a strike against an aluminum manufacturer, determining the amount of coins stolen by parking meter collectors in New York City, determining in a gambling prosecution whether an electronic poker game is essentially one of chance or of skill, establishing disputed paternity, and measuring the probability of reversal in contested elections.

The chapters are fairly technical in content and sometimes contentious in argument. This may reflect the infectious nature of the adversary process, and that may serve as an additional lesson for the book's statistical readers. Indeed, the editors have borrowed a characteristic invention from the adversary system and use it to good advantage. Half of the chapters are followed by comments from statisticians who do not share the chapter authors' views on technical statistical issues. And half of the comments are followed by rejoinders from the authors. A particularly good example is the exchange between D. A. Conway and H. V. Roberts (who defend the use of reverse multiple regression analysis—a technique that generally produces results favorable to defendants—in a federal employment discrimination suit in which Roberts was an expert for the defendant bank) and Stephan Michelson (the government's chief statistical expert in the same case). Their debate succeeds in creating some of the feeling of a battle of experts.

By using such exchanges the editors illustrate for readers some of the virtues of the adversary process. At its best, the adversary process is unequaled in its ability to identify and make salient areas of disagreement, expose assumptions, and compel expert witnesses to make themselves understood. The readers of most statistics (or other scientific) books or journals would conclude that a high degree of agreement and certainty reigns. By contrast, in the short scope of this one book an impressive sampling of disagreement about fundamental statistical theory is displayed. The lesson for statisticians who will enter the legal arena is to expect comfortable assumptions to be questioned vigorously.

From these presentations a number of themes emerge. The most important of these center on substantive applied statistical issues, ethics, and the challenge of communicating statistical ideas to non-statisticians in legal forums.

One issue after another pertaining to the correctness of statistical application is held up and debated in chapter after chapter.