



Chemical Risk Assessment — The Navy Occupational Approach

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In order for the Department of the Navy to withstand tests of its ability to manage occupational hazards, the essentials of risk assessment and risk management have been practiced for some time. A recent literature review indicates numerous citations dating from 1925 to the present.

Key documents pertinent to risk assessments are OPNAV INST 4110.2, "Hazardous material control and management," and BUMED INST 6270.8, "Procedures for obtaining health hazard assessments pertaining to operational use of hazardous materials." Like others, we believe that the actual steps of risk assessment are 1) the characterization of the exposure of a risk group, 2) evaluation of experimental studies, 3) calculation of risks and cases, and 4) calculation of an acceptable concentration or other end point.

While elements of risk assessments as evidenced by the historical development of our Navy programs are not new, our finished risk assessment strategies have yet to be developed. We are still primarily involved with the first step of characterizing exposures of our risk groups.

We possess significant strengths in terms of the Navy System Safety Program, which is mandated by OPNAV INST 5100.24A of October 3, 1986. Although the language of this instruction does not specifically identify risk assessment, system safety strategies are useful in the development of probable exposure scenarios.

Naval decision-making is often a form of risk assessment. Our challenge is that of applying scientific methodologies, such as those described in this conference, with time-honored risk assessment strategies learned at sea and in the field.

Introduction

In order for the Department of the Navy to withstand tests of its ability to manage occupational hazards, the essentials of risk assessment and risk management have been practiced for some time. A wide range of activities afloat and ashore require occupational and environmental health and safety support. A recent literature review indicates numerous citations dating from 1925.

In an era of increasing budgetary concern, it is often difficult to justify the Navy occupational and environmental health and safety programs. An understanding of risk assessments by managers may provide important insights into effective allocation of resources and foster sound decisions on control measures which act to minimize risks.⁽¹⁾

History

This is by no means an encompassing review of all Navy efforts in the area of risk assessment pertinent to occupational and environmental health and safety. These are simply illustrations of the dedicated efforts of countless men and women who have devoted their professional activities to the protection of Navy and Marine Corps personnel.

1920s

The history of Navy industrial hygiene and occupational medicine dates from 1922 when efforts began to protect civil servants in Navy shipyards. In 1925, the Philadelphia naval shipyard conducted a survey of lead poisoning and recommended control strategies. The modified Burrell gas mask was recommended as protection against inhalation of lead fumes from shipbreaking World War I dreadnoughts.

The Philadelphia yard was the scene of additional efforts to prevent plumbism.⁽²⁾ Sixty-two years later, Navy Lieutenant Lindsay Booher's paper on "Lead Exposure in a Ship Overhaul Facility During Paint Removal" would appear.⁽³⁾

1940s

World War II saw broad occupational health programs including preemployment examinations, injury care, medical surveillance, and industrial hygiene field surveys. The organization of medical services corresponded to the 12 naval districts. Emphasis was placed on conservation of manpower, with industrial hygiene and safety still in their infancy.⁽⁴⁾ Unfortunately, by 1946, industrial health activities were demobilized.⁽⁵⁾

The shipyards were the consistent focus of the Navy's efforts. Through professional associations and publications, we have always benefited from the efforts of private shipyard industrial hygienists. In 1945, F.J. Viles studied the volume of welding fumes produced during arc welding operations and devised alternatives in terms of local and general exhaust ventilation.⁽⁶⁾

In 1943, Voegtlin and Watts⁽⁷⁾ documented their largely unsuccessful treatment of service members who had accidentally ingested methyl alcohol. It is somewhat ironic that a similar alcohol ingestion incident occurred during Operation

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Desert Storm. Today, we would call this area of endeavor clinical toxicology, but it is nonetheless part of the legacy of Navy medicine.

Critical mistakes have occurred in the assessment of risk. A report involving chest X-ray and microscopic analysis with respect to asbestos dust exposures concluded that the incidence of asbestosis was low for employees with more than 20 years of exposure.⁽⁸⁾ It is always important to understand critical differences between survey findings (which are preliminary) and true studies that reflect proper experimental design.

1950s

In the post-World War II era, demobilization contributed to the demise of industrial health activities. There is a paucity of published data from the 1950s. A 1959 publication examined the nature of occupational health and safety programs for civilian employees, noting the role of the Bureau of Employees' Compensation and the Civil Service Commission.⁽⁹⁾

Techniques ranging from general ventilation using axial blowers to protective clothing (impermeable suits, head coverings, goggles, and air-line respirators) were used during the 1950s. These techniques were an attempt to minimize the risks of explosion and worker exposures to methyl isobutyl ketone and diluent toluene used in spray-painting ship interior spaces.⁽¹⁰⁾ Heavy emphasis was still placed on explosion potential.

Viet Nam to 1992

In the 1960s, Public Laws 658 and 1028 formed the legislative foundation for the Navy's program, which included treatment of occupational injuries and illnesses, emergency treatment of on-the-job illnesses and medical conditions, and other activities.⁽¹¹⁾ One of the precipitating factors in the development of Navy occupational safety and health programs was the highly publicized series of aircraft carrier fires of the 1960s.⁽¹²⁾

Special duty assignments such as diving and other special warfare skills also prompted the development of special techniques and assessments. Collison et al.⁽¹³⁾ pioneered the development of a direct and rapid gas chromatographic procedure for the determination of carbon monoxide in blood in which the carbon monoxide normally bound to hemoglobin is released. The method was applied to Navy divers.⁽¹³⁾ Given the recent heightened interest in bioaerosol monitoring, it is somewhat ironic that Wright et al.⁽¹⁴⁾ addressed bioaerosol considerations relative to habitability and health issues as early as 1968.

The linkages between industrial hygiene and safety were crucial to the development of Navy safety and health programs in the years following passage of the Occupational Safety and Health Act in 1970. A prime example of risk assessments peculiar to the Navy can be found in the case of

Otto Fuel II, a liquid propellant used for MK-46 and MK-48 torpedoes. Rivera⁽¹⁵⁾ published one of the first papers regarding this propellant in *U.S. Navy Medicine*. The critical nature of submarine atmospheres has contributed to expertise in terms of 90-day exposure standards for chemicals.⁽¹⁶⁾ There is no more Navy-unique area of risk assessment than this type of analysis.

Sometimes our failures have attracted as much attention as our successes. When an automated film-developing machine was incorrectly connected to a ship's drinking water lines, 544 crewmen succumbed. Symptoms included gastrointestinal disease and elevated white blood cell counts.⁽¹⁷⁾ Ship design and repair continue to be two very important areas for risk assessment.

The 1980s saw a major attempt to develop a computerized system to monitor medical information and to generate lists of hazardous substances.⁽¹⁸⁾ The electronic basis for Navy occupational and environmental health recordkeeping is undergoing vast changes at present. Navy authors have also played prominent roles in assessments with respect to composite fiber field studies in recent times.⁽¹⁹⁾

The preceding discussion does not encompass all occupational health efforts in the area of risk assessment; for example, there are many contributions made by the Navy Medical Research Institute (Toxicology Detachment) that will be outlined later in this volume.

Regulatory Framework

Key documents pertinent to risk assessments are OPNAV INST 4110.2, "Hazardous material control and management," and BUMED INST 6270.8, "Procedures for obtaining health hazard assessments pertaining to operational use of hazardous materials."

Planners often speak of conceptual models of activities. The Navy conceptual framework for chemical risk assessments is built around a medical model. This basically means that we are sensitive to certain past errors that have led to overexposure and have resulted in disease. Moving beyond the assessment of risk, we have devised systems of analysis and remediation that seek to extend coverage to related substances and to similar exposure scenarios.

As an occupational health team, we work with safety professionals and managers, health-care providers, and individuals specifically trained in occupational health, including physicians, nurses, industrial hygienists, and others. Although it might seem that a highly organized scheme would work best for risk assessment, it is also true that diversity of interests leads to a desirable synthesis.

An examination of federal legislation and regulation regarding toxic substances will reveal that early efforts directed at limiting toxic releases or concentrations in media have moved toward a more thorough examination of a material's characteristics before its use. Since 1973, federal

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health and safety statutes have adopted a general safety standard of "unreasonable risk" (e.g., Consumer Product Safety Act of 1973, the Federal Environmental Pesticide Control Act of 1973, and the Toxic Substances Control Act of 1976).

While we to date have not adopted "acceptable lifetime risk" figures, the Navy has followed this general pattern by moving toward controls related to the introduction and dissemination of hazardous materials.

We are students and observers of this conference and other forums for dissemination of information concerning the "acceptable lifetime risk" issue. Although the Occupational Safety and Health Administration (OSHA) may use the criterion of 1 "cancer" death per 1000 workers (1:1000) as an acceptable lifetime risk, others agencies differ. The Nuclear Regulatory Commission (NRC) opts for the ratio of 1:400 for occupational exposures, whereas the Food and Drug Administration (FDA) has interpreted court decisions to mean that a lifetime risk of 1:1,000,000 is a *de minimis* level of cancer risk (e.g., insignificant and therefore acceptable). The Navy precedent is probably based on radiation exposures where we closely followed the NRC's recommendations.

We must remember, however, that individuals may be exposed to a mixture of many substances both on the job and away from the work site. Thus, the issue is one of assessing integrated exposures. Modern techniques of biological monitoring and medical surveillance must be coupled with traditional air sampling methodologies.

The Navy has developed procedures for obtaining health hazard assessments pertaining to operational use of hazardous materials (BUMED INST 6270.8 of June 6, 1990). This instruction has the trivalent goal of 1) minimizing health hazards posed by materials or systems under development, 2) establishing formal procedures for obtaining additional toxicological information for those materials, and 3) assigning responsibilities within the Navy Medical Department for performing risk assessments.

By viewing research and development in life sciences as integral to all other research activities, BUMED INST 6270.8 attempts to ensure that risk assessments are performed early in the process. Not only is there a question concerning new materials, but the assessment process must extend to new uses of existing materials.

One of the key elements of OPNAV INST 4110.2 is the use of the term "life-cycle material and equipment requirement." With this term is a realization that the problems we encounter continue through our use and disposal (e.g., recycling) of substances.

Navy Risk Assessments

Like others, we believe that the actual steps of risk assessment are 1) the characterization of the exposure of a risk group, 2) evaluation of experimental studies, 3) calculation

of risks and cases, and 4) calculation of an acceptable concentration.⁽²⁰⁾

We similarly recognize the classification of the risk assessment process into four broad components: hazard identification, dose-response assessment, exposure assessment, and risk characterization.⁽²¹⁾

Although elements of risk assessments are not new, as evidenced by the historical development of our Navy programs, our finished risk assessment strategies have yet to be fully developed. We are still primarily involved in the first of four steps; i.e., characterizing exposures of our risk groups. As always, this means consideration of the human focus of the exposure, the concentration of exposure, the route of exposure, the duration of exposure, and the nature of exposure to other toxic materials that may be concurrently released.

Intense regulatory pressures and workers' compensation claims have combined to narrow our interest primarily to occupational issues. We are in the process of broadening these techniques to include other environmental concerns. Although we attempt to describe exposures to particular individuals, we still suffer information shortfalls in terms of inferential means of applying these results to other individuals (whose work patterns may differ).

Characterization of the Exposure of a Risk Group

One of the most useful techniques is the preliminary description of a possible exposure scenario. This usually involves asking a series of questions as to the nature of the release (e.g., when, where, and how the release may occur; what is in its vicinity; and what is known about the amounts and characteristics of the released agent). Remembering that this represents a hypothetical scenario, some means of organizing these factors is necessary.

One very useful way to organize events is to use an event-tree or other system safety device. The U.S. Navy has significant strengths in terms of the Navy System Safety Program, as mandated by OPNAV INST 5100.24G. Although the language of this instruction does not specifically identify risk assessment, the instruction is specific in commanders' requirements that their subordinates must "establish procedures to ensure timely follow-up to correct identified hazards, and document with proper justification management decisions to accept risks associated with identified hazards."

Evaluation of Human and Animal Studies

Other papers in this volume will outline the qualitative and quantitative evaluation of human and animal studies, which involves weighing many aspects of the respective experiments. The calculation of risks and cases for non-threshold and threshold toxicants follows this step.

Much of this work is assigned to the Toxicology Detachment. The mission statement of the Navy Medical Research

Institute (NAVMEDRSCHINSTITUTE INST 5450.1D of November 26, 1990) charges this detachment to formulate occupational and environmental health hazard evaluations and risk assessments, including appropriate personnel exposure limits. It also charges the Toxicology Detachment to develop and maintain a cadre of Naval personnel skilled in the disciplines of toxicology, health hazard evaluations, and risk assessment.

Assigning Acceptable Concentrations

Historically, we have relied upon OSHA's Permissible Exposure Limits or the Threshold Limit Values and Biological Exposure Indices from the American Conference of Governmental Industrial Hygienists for the interpretation of occupational exposures. It is becoming more incumbent upon us to derive acceptable concentrations, not only for workroom air but also for other media and environments. As it becomes more difficult to complete this task, we are made aware of the presence of particularly susceptible individuals in the workplace for whom such standards may be misleading.

Although the Department of the Navy is not a regulatory agency, we are affected in our thinking by confusion concerning the use of conservative, realistic, and worst-case exposure scenarios. Regulatory agencies, most notably the U.S. Environmental Protection Agency, have been affected by Executive Orders 12291 and 12498, which reflect the Office of Management and Budget's concern over worst-case exposure scenarios. Numerous cases exist in which there is difficulty in assigning the scenario conditions.

Lessons Learned from Operation Desert Storm

Chemical and Biological Weapons Defense

Chemical and biological agents may be of the ordinary type or they may be warfare specific. Before and during Operation Desert Storm (ODS), efforts were focussed on many elements of risk assessment relative to chemical and biological weapons. Ironically, while use of these instruments of human misery was curtailed, the Iraqis set hundreds of oil wells on fire and released million-gallon quantities of crude oil into the Persian Gulf.

In our assessment of military risks pertinent to chemical agents, we must now acknowledge the combined effects of warfare agents plus petroleum and/or warfare agents plus industrial chemicals. We must address the purposeful use of industrial chemicals for lethal purposes. Critical issues exist with respect to monitoring and decontaminating chemical warfare agents when industrial pollutants are present.

One serious challenge in developing a conceptual framework for protection from or neutralization of biological and chemical agents is that it is difficult to envision the purposeful use of toxic substances. Workers are infrequently exposed to tiny, almost immeasurable concentrations; in con-

trast, enormous concentrations of chemical substances may exist on a battlefield and extend to civilian communities.

The use of chemical and biological weapons is not an issue for only military personnel. These weapons are prohibited because they do not discriminate between military and civilian populations. If unleashed, these agents will have significant effects, beginning with the very young, the very old, and the most infirm individuals, all of whom are most susceptible to toxic substances.⁽²²⁾

Oil Smoke Toxicity Issues

As clouds of dense smoke rose from the burning oil fields of Kuwait, data concerning the nature of exposures to United States personnel became critical. It was necessary to record and archive these transient exposure conditions.

Simple monitoring of combustion-product pollutants was conducted, along with evaluation of fire safety procedures. Using a team skilled in occupational and environmental health and safety, multi-agency monitoring has begun to address exposures to crude oil, volatile hydrocarbons, sulfur-containing compounds such as hydrogen sulfide, combustion products, and other agents and stressors.

Exposure monitoring was intended to form the basis for the design of epidemiologic studies. When critical exposures are identified, we will seek to identify both exposed and unexposed groups. From a health effects standpoint, we wish to examine the spectrum that begins with exposure and possibly extends through the stages of biochemical and histopathological changes, organ system dysfunction, and organismal disability.

Future Concerns

Concern obviously exists because of the ecotoxicological hazards stemming from the oil, its constituents, and its combustion products. Operation Desert Storm contains important lessons related to occupational and environmental health. The importance of these lessons is underscored by operational issues that require detailed assessment of risks and hazards.

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