RISK MANAGEMENT IN THE U.S. AND JAPAN: A COMPARATIVE PERSPECTIVE

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ABSTRACT

Risk management practices are the result of scientific risk analysis, subjective risk evaluation, governmental policy, economic concerns, interest group pressure, and cultural influences. One way of analyzing the relative influence of scientific, cultural and political factors is to examine how decisions for similar risks are made in different countries. Cross-national comparisons may suggest new or alternative approaches to improving the interaction between risk assessment and risk management.

In this paper we examine the risk management process in the United States and Japan through four cases studies (lead, detergents, pesticides, and seat belts). This requires identification of the involved actors, and an understanding of how they are involved; the role of risk analysis in risk management; and the underlying structure. Finally, we ask how similar or dissimilar the U.S. and Japanese processes are in these terms.

This analysis is based on the results of a two-year comparative study of technological risk management in the U.S. and Japan. The work was sponsored by the National Science Foundation, the Japan Society for the Promotion of Science, and the Environmental Protection Agency.

KEY WORDS: Risk management, Risk assessment, U.S. and Japan.

1. INTRODUCTION

Technological hazards are universal, but the means of dealing with them are not universally the same. Different countries will, based on cultural, economic and political differences, manage the same risks differently. A small number of studies have employed a cross-national perspective to compare risk management approaches in several areas (Brickman, Jasanoff, and Ilgen, 1985; Lave and Menkes, 1985).

The object of these cross-national studies is to, first, learn by sharing experiences. The more long-term objective is to profit from this sharing, in areas related to methodologies, data collection, analysis, or the utilization of the results, that might enhance the effectiveness of future technological risk management practices.

This study, which was sponsored by the National Science Foundation and the Japan Society for the Promotion of Science, examined risk management practices in the United States and Japan. The study was begun in October, 1983, included a bilateral workshop with leading U.S. and Japanese participants in October, 1984, and will soon conclude with the publication of a Workshop Proceedings and a Final Report.

2. HISTORICAL PERSPECTIVE (Covello, et al., 1985)

In the U.S. and Japan major changes have taken place in the nature of the risks that each society faces, as well as in the social and political context for risk analysis and risk management efforts. For example, there has been a significant shift in the nature of the risks to which U.S. and Japanese citizens are subject. In 1900, the leading causes of death in both countries were infectious diseases--pneumonia, influenza, and tuberculosis. By mid-century, infectious diseases had been displaced by chronic degenerative diseases of adulthood--especially heart disease and cancer (National Academy of Science, 1979; Foreign Press Center, 1982).

Although there has been no substantial change in the rank of accidents as another leading cause of death, there has been a shift in the types of accidents The rate of fatal accidents in mines, for example, has fallen substantially as has the average annual rate of fatal accidents in factories in the U.S. and Japan. Natural hazards still cause substantial property damage in both countries, but such events account for only a small number of annual fatalities.

While these types of accidents have been declining in significance, other types have increased. In 1900, for example, the number of automobile accidents in the United States was insignificant; however, in 1980 automobile accidents accounted for over 50,000 deaths (Claybrook, 1983). Although the number of automobile accidents in Japan is much smaller (around 9,000 in 1982), the fatality rate per vehicle mile in 1980 is 37% higher than that in the U.S. (Kasperson and Sakashita, 1984).

Next, in the U.S. and Japan there has been an increase in the role of the central government in managing risks. There have been dramatic increases in: (1) the number of major environmental laws, and (2) the number of national agencies charged with managing health, safety, and environmental risks. In the U.S. attempts have recently been made to reverse the trend toward growth in federal regulatory involvement; however, several factors have contributed to its continuation, including the increasing health, safety, and environmental consciousness of the nation; a decline in the level of public confidence in business; the emergence of the public interest movement; and the growth of a complex, interdependent, highly technological society. Additional factors leading toward continued national regulatory involvement include:

- An accelerating rate of technological change, resulting in enormous increases in the physical and temporal scale and complexity of risks [for example, approximately 70,000 chemicals are in current use, with perhaps 1,000 new chemicals being introduced each year];

- An increase il the speed of scientific and technological developments, leading to shorter and shorter time lags between scientific experimentation, development, and entrepreneurial production;

- The increasing role of government as a producer of risks through its sponsorship of scientific and technological research and development;

- The rising cost of technological risk control and damages.

In Japan, many of the factors have been pronounced. The rate of technological change in Japan equalled if not exceeded that of the United States. In Japan the devastation of World War II required Japan to rebuild her technological and industrial base (Ikeda, 1984). Japan has been transformed into a technological and economic superpower, bringing in its wake the concomitant problems of advanced industrial society.

The turning point in Japan's governmental involvement in risk assessment and management can probably be traced to the 1970 "pollution Diet," a special session during which 14 pollution bills were passed (Reed, 1981). Japan's Basic Law was revised, for the first time assigning greater priority to environmental protection than to economic growth. On July 1 of the next year, the Japanese government created the Environment Agency, which assumed the leading role in monitoring and regulating environmental issues (Kelly et al., 1976). The changed emphasis on environmental quality, even at the expense of economic growth, was maintained even through the oil crisis, and was in fact only relaxed in 1978 in order to create a situation of "peaceful coexistence" between economic growth and environmental protection requirements (Reed, 1981).

Finally, in the U.S. and Japan there has been an increase in the participation of special interest groups in the societal risk management process. Risk analysis and risk management activities have become increasingly politicized, with virtually every major health, safety, and environmental decision subject to intense lobbying by interest groups representing industry, workers, environmentalists, scientific organizations, and other groups (Edwards and von Winterfeldt, 1984). Not only has there been an increase in the number of such groups and their members, but also substantial growth in their scientific sophistication and modes of operation.

In contrast to the American experience, interest groups on environmental issues in Japan have tended to be localized or issue-specific. There are in Japan no broadly based environmental or public health organizations similar to the Sierra Club or Environmental Defense Fund in the U.S.

In Japan, "Kogai" (public nuisance) became a fundamental political issue during the 1960's and 70's, leading to the rise of "Anti-Kogai" citizen's movements (jumin undo) consisting of individuals directly or indirectly impacted, or likely to be impacted, by development projects (Ikeda, 1984). These jumin undo urged the government to take prompt remedial measures to mediate the growing conflicts between economic interests and damage to the environment. Using tactics ranging from "humble requests" to sitdowns, demonstrations, and challenges through the court system, they have helped block industry expansion (Kelley et al., 1976) and in some cases (such as Minamata Disease) helped secure victim compensation.

3. SUMMARY OF RISK MANAGEMENT APPROACHES IN FOUR CASE STUDIES

Case Study Selection

We approached the task of comparing risk management in both countries through comparison of several carefully selected cases of technological risk management. Among the issues which affected case study selection were:

1) Similarity of the issue in both countries.

2) The representativeness of current risk management practices.

3) Sufficient issue duration.

4) Extensiveness.

5) Availability of data.

Based upon these criteria, four case study topics were selected:

1) risks from detergents;

2) seat belts;

3) risks from lead; and

4) pesticides.

Detergents

The detergents case shows close similarities between the U.S. and Japan. In both cases it is local, rather than national, governments that have generated the most stringent enforcement

In both Japan and the U.S. problems were similar: how to manage eutrophication risks in bodies of water, risks which might be increased by the use of phosphates in synthetic detergents? In large part the answers were the same, with the Japanese response predicated on the U.S. experience. In the U.S., the detergent industry originally attempted to substitute NTA; questions about its safety led to a second strategy of reducing phosphorus use. The phosphorus content of detergents dropped from 9-12% in 1970 to about 6% in those areas of the U.S. which had not instituted a phosphorus ban.

There is considerable variance in the amount of wastewater which is treated in the two countries. In the U.S., most wastewater is treated in some form. As implementation of wastewater technology in the U.S. continues to increase, more U.S. wastewater will be treated for phosphate removal.

In Japan, a significantly lower percentage of wastewater, about 30%, is treated. In the wake of the Eutrophication Prevention Ordinance, the design of the sewerage plant located closest to Lake Biwa, the largest lake and a principal water supply source in Japan, was altered to include nutrient removal. This plant began service in April, 1982, several years after the problem had become serious.

There are varying perceptions of the role of government in the U.S. and Japan. Sueishi and Nishimura describe the "chushuku" system, which suggests that the Japanese government takes a paternal role, and there is a reluctance on the part of government officials to deal frankly with issues which appear to be outside of governmental control. In the detergent area, the role of governmental control is manifested in information availability. In the U.S., research findings are often disseminated and generally fully disclosed. In Japan, on the other hand, there appears to be an absence of information-sharing outside of the government.

Seat Belts

In both the U.S. and Japan, traffic fatalities increased in the 1960's. By 1970, 16,765 fatalities occurred in Japan. This trend reversed in the 1970's, and in 1979 there were only about half as many traffic fatalities as in 1970. However, fatalities began to increase again in the early 1980's.

The number of annual traffic fatalities in the U.S. passed 50,000 in the middle of the 1960's and stayed around 52,000 or 53,000 until 1972 when traffic fatalities reached an all-time high of 54,589. However, traffic fatalities decreased by almost 9,000 due partially to the federally mandated 55-mph speed limit. Traffic fatalities gradually increased afterward and in 1979, traffic crashes were responsible for the death of 51,093 Americans and the disabling injuries of an additional two million.

It should be noted, however, that the annual fatality rate in Japan declined from 8.0 per 100 million vehicle miles in 1975 in 4.8 in 1980. By comparison, in the U.S. the annual fatality rate showed little change from 3.35 per 100 million vehicle miles in 1975 to 3.34 in 1980.

Seat belt usage is low in both the U.S. and Japan: average usage is under 20 percent. Japan requires the driver to fasten the seat belt and to "strive" to have passengers fasten theirs when driving on national expressways. The U.S. now requires child safety seats in all 50 states and has passed mandatory seat belt usage laws in a few states.

Lead

In Japan, the Ushigome-Yangicho incident in Tokyo (May, 1970), acknowledged the risk of exposure to lead. Although health officials found no significant evidence of elevated blood lead levels in the residents tested, the issue become significant to the unions and local political groups. Responses by the Ministry of International Trade and Industry (MITI) called for a lowering of the lead content in gasoline from 8.96 gm/l to 3.28 gm/l in June, 1970. An expert committee was assembled in August, 1970, and the committee outlined a schedule for reduction of lead content in gasoline which resulted in the level of lead in gasoline being 0.15 gm/l by April, 1975. A total ban of lead was considered, but leaded gasoline remained available as premium gasoline for older cars which required lead for mechanical reasons. Government subsidies assisted refineries to increase the production of unleaded gasoline.

In 1975, the Environmental Protection Agency was sued to list lead as a pollutant under the Clean Air Act. This action was challenged, but lead was listed as a pollutant in 1976, and air quality criteria and the proposed standard were developed. The air quality criteria document determined that over 88% of the ambient air lead resulted from the combustion of leaded gasoline. A phasedown in lead was outlined, but the oil crisis of 1978 delayed the reduction of the lead content in gasoline.

The target population at risk from the health effects of lead in the blood were children under six years of age. Occupational exposure also resulted in ambient air quality limits in the workplace. Misfueling, additional information concerning health effects, and greater consumption than anticipated have resulted in additional reduction of lead in gasoline, from 1.10 gm/gal (0.29 gm/l) to 0.1 gm/gal (0.026 gm/l).

In both cases, the impact of leaded gasoline on the catalytic converters in automobiles played a major role in reducing lead in gasoline. Catalytic converters were installed to reduce non-lead pollutants, but the lead fouled the catalyst making the converters ineffective. In Japan, air quality was a major concern as well as the economic significance of the export market to the U.S. Technological developments provided engines that did not require catalytic converters to achieve the air quality emission standards.

Pesticides

Specially synthesized organic compounds became commercially available for pesticide applications (insecticides, herbicides, fungicides, antimicrobials, and other special applications) beginning in the 1940's. These compounds--organic chemicals such as DDT, parathion, BHC--proved to be highly potent for pest control and relatively rapidly displaced many older, less effective inorganic pesticide formulations. In agriculture, they opened new avenues for managing production, by stabilizing crops against pest destruction, improving yields, and underwriting a shift toward less labor-intensive production. Other important uses have included food and grain storage.

The use of synthetic organic pesticides increased rapidly in both Japan and the United States from the late 1940's onward. In Japan, the use of pesticides has increased dramatically even as agricultural land has slightly declined. The area of agricultural land in Japan averaged 6.2 million hectares in the 1960's but was marginally lower, at 5.8 million hectares in the 1970's. Pesticide use meanwhile climbed from 130 million pounds of on-line pesticide ingredients in 1960, to 180 million pounds by 1970, and more than 350 million pounds by 1980.

While the magnitude of pesticide use in the U.S. is sizeable and growing, the intensity of use has been markedly less than in Japan. U.S. agricultural land averaged 438.9 million hectares in the 1960's and 433.2 million hectares in the 1970's. In 1960 over 304 million pounds of pesticides were being applied annually. Pesticide use increased to 515 million pounds on average during the 1970's and by 1980, was about 605 million pounds. During the 1970's, then, Japanese farmers were using some 31 pounds of pesticides per hectare; by comparison, the American farmer was using an average 1.19 pounds per hectare.

There are numerous parallels in the situation encountered and the regulatory procedures evolved as Japan and the U.S. have sought to cope with chemical pesticides. The content of technical studies undertaken in each country's management process is largely the same. Each country utilizes basically a two-step management process. Prior to commercial sale and use, pesticide compounds are subjected to registration review and assessment (including necessary technical studies). Second, post-registration review and assessment continue as warranted; registration status and conditions may be revised or ultimately rescinded as new evidence on effectiveness and the impacts of use becomes available.

Foremost among the differences is the formal status accorded to risk/benefit evaluations in pesticide assessment. In the U.S., the Special Review procedure formalizes quantitative risk/benefit studies in the management process. There is, however, no parallel for this procedure in Japan. Quantitative risk/benefit studies are not formalized in the Japanese pesticide management process. Such analyses, when conducted, tend to be rather judgmental in character.

4. CONCLUDING REMARKS

Realizing that there are exceptions to any generalizations, and that four case studies and a workshop do not provide a broad foundation, it may nonetheless be useful to compare risk management in the U.S. and Japan along several dimensions. We found it useful to compare the approach to, and the structure of, risk management and draw obvious and non-obvious implications.

Approach to Risk Management. We can compare the Japanese approach, which tends toward negotiation and administrative guidance, with the U.S. approach of management by regulation. Much has been made of the Japanese ability to operate by consensus rather than law. In some cases, this tendency is regarded enviously, as in the tendency to regard management-labor relations and business-government relations in Japan as operating more smoothly than "adversarial" relations in the U.S.

We found that informal coordination was practiced more widely in Japan than in the United States, so there is some basis for accepting these generalizations for both the U.S. and Japan. The Japanese do practice a more coordinative approach to risk management, while we need remind no one of the adversarial and sometimes acrimonious relations between regulators and regulated in the U.S.

Risk Management Structure. Japan has an informal approach to risk management that utilizes an ad hoc committee evaluation. The committee is comprised of experts in the given area, and the committee's results are not publicly disclosed. The risk management structure, in Japan, tends to be centralized.

By contrast, in the U.S., risk management is more formal, open, and information is widely disseminated. Although much of the structure is centralized in the federal government, many of the federal laws encourage decentralization of authority to state agencies. Furthermore, local or state jurisdictions enact regulations that may be more strict than federal regulations.

Risk analysis and management are institutionalized processes in the United States. For example, in the case of pesticides, the FPAR process not only provides for risk analysis, but also for risk/benefit analysis.

There is no institutional analogue in Japan. The same goes for users of restricted pesticides: certification is required in the U.S., but not in Japan.

Centralization/decentralization is also important in the development of risk issues. In Japan, local interest groups, supported by the mass media, tend to bring risk issues into the government's awareness as demonstrated by the blood lead poisoning incident of newspaper workers, in the lead case study, and the water quality of Lake Biwa in the detergents case study. In the U.S., issues tend to gain national recognition through organized national interest groups, such as the Environmental Resources Defense Fund which initiated the law suits resulting in lead regulation under the Clean Air Act.

Obvious Implications. Given that Japan relies on negotiation and coordination to manage technological risks, Japan appears to have a system which is efficient in the economic sense. Issues would not tend to become a matter of public debate, but instead be a matter of negotiation between parties which are relatively "expert," that is, risk producers and risk regulators.

In contrast, the U.S. appears adversarial and therefore inefficient. Relations between risk producers and risk regulators tend to become confrontational. Many issues become a matter of public debate, and after interest groups have become involved, there may be some risk that scientific input loses influence in the public debate.

Non-Obvious Implications. At the same time, we need to ask whether there are non-obvious implications in a consensual versus an adversarial approach. It appears there may be. We found that Japanese participants in the workshop continued to mention the lack of public confidence that the Japanese government was doing a good job of protecting them from risks. Because the debate was most often "behind closed doors," nothing appeared to be happening. Therefore, public perception was that risks were being either mis-managed or simply not managed at all.

By contrast, an open, more adversarial approach in the U.S. at least created the public perception that risks were being dealt with. Of course there is always the strong possibility that risks would be perceived as being mismanaged, but less possibility of a public perception that nothing at all was being done.

This study comparing technological risk management in the U.S. and Japan is part of a small, but growing literature on cross-national risk management comparison. As mentioned earlier, Lester Lave and Joshua Menkes have explored risk management in the U.S. and West Germany. In addition, Ron Brickman, Sheila Jasanoff, and Thomas Ilgen have completed a study which compares policies for regulating toxic chemicals in the U.S., Britain, France and West Germany.

These studies are useful but just scratch the surface. There is a need for both research breadth (more countries entered into a comparative framework) and depth (more cases, and a more finely-structured framework with which to analyze cases).

Attempts are being made to develop a second U.S.-Japan workshop that would examine the technical aspects of risk assessment in both countries. With this study of risk management as a background, examination of techniques regarding risk assessment would provide the basis for further scientific and technical exchange between the two countries.

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RISK EVALUATION OF HAZARDOUS WASTE DISPOSAL SITES USING FUZZY SET ANALYSIS

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Evaluation and ranking of controlled hazardous waste sites can be made using a relatively new technique referred to as Fuzzy Set Analysis. The methodology presented is applicable to multiple alternative decision making, when criteria are of unequal importance, and is based on the concept of establishing a subjective value for each alternative according to each criterion, and then raising the subjective value to a power commensurate with the relative importance of the criterion. This exponential weight is calculated on the basis of a preferential analysis of criteria comparisons. Apart from ranking the alternatives, Fuzzy Set Analysis provides a quantitative representation of the community opinion of the order of importance of the criteria, regardless of the sites being considered. Based on the importance factors averaged from a cross section of the community, public concern could also be ranked.

KEY WORDS: Risk, Hazardous Waste, Fuzzy Set, Ranking, Subjective Variable, Alternative Decision Making

INTRODUCTION

Under the Hazardous and Solid Waste Amendments of 1984 (Section 3019 of RCRA), owners of hazardous waste disposal sites using landfill operations or surface impoundments are required to amend RCRA Part B permit applications to include information on the potential for the public to be exposed to hazardous wastes as a result of their operations.

According to the EPA's guidance manual, the owner should draw conclusions regarding the potential for and possible magnitude of human exposure from both normal operations and accidents at or near the unit(s) of concern, for each unit and for each pathway. The owner should also discuss the potential for direct human exposure and the potential for human exposure from the contamination of food chain crops. In particular, the owner should describe the site-specific location, design, and operating factors that reduce the potential for releases as well as factors that increase the potential for exposure.

To comply with EPA guidelines, an analysis should be performed for each of the following potential exposure pathways:

- groundwater
- surface water
- soil
- air
- subsurface gas releases
- transporation-related releases
- worker-management practices

As was the case for the implementation of CERCLA (i.e., Superfund), the EPA may be required to identify the facilities warranting the highest priority for remedial action. When setting priorities, criteria may be established based on relative risk through the Hazard Ranking System (HRS) or a similar model. The ramifications of submitting exposure information could range from "no action" by the EPA to complete shutdown of the facility.

Matrix Evaluation Analysis

Numerical matrix approaches, such as the HRS, have been used to evaluate and rank hazardous waste sites in order to prioritize remediation efforts. Due to the non-quantifiable nature of the criteria, these matrices are built using subjective values whose unitless natures require that the values be weighted according to the importance or significance of the criterion. Consequently, the values are adjusted to account for the inequality of the criteria. Several techniques are used to weight criteria values, and each attempts to reach a decision with a minimum degree of bias. The use of a priori assignment of weighting factors has been widely used in recent years. This approach involves assigning the criteria weights by the study team based upon experience and knowledge of the criteria.

Another popular approach is the "Delphi Technique" of gathering a diverse assembly of individuals who, as a group, assign weights to the criteria. Following the criteria weighting, the values for each alternative are adjusted accordingly, and the sites are then compared. "Sensitivity tests" are performed by changing the criteria weights or criteria values, or both, to determine if the final site ranking is changed by these slight adjustments. The purpose of the sensitivity test is to introduce the element of tolerance limits to the analysis.

Regardless of the inherent shortcomings, it is apparent that subjectively-based, weighted matrix analysis represents the state of the art for disposal site evaluation in today's regulatory environment. Thus, it remains industry's responsibility to seek new approaches to improve the methodology to provide better and more reliable decisions.

Fuzzy Set Analysis

At best, the decision to distinguish one site from several alternatives can be a tortuous and time consuming effort. Advances in decision theory and the availability of computers to store and manipulate large amounts of information can simplify this effort.

One methodology (Yager, 1977) recently developed for multiple alternative decision making, when criteria are of unequal importance, is based on the concept of establishing a subjective value for each alternative according to each criterion, and then raising the subjective value to a power commensurate with the relative importance of the criterion. This exponential weight is calculated on the basis of a preferential analysis of criteria comparisons.

A detailed review of Fuzzy Set Analysis can be found in Zadeh (1973) and Kaufman (1975). Briefly, Fuzzy Set Analysis refers to a consideration of multiple alternatives according to multiple criteria. When the number of alternatives and criteria is small, the human mind is capable of "keeping things in order"; however, when the alternatives or criteria are numerous, the "fuzziness" of the matrix is pronounced so that significant information is either suppressed or ignored. To remedy this, the relative importance of the criteria is determined in a separate matrix analysis and is applied as a vector weighting to the alternatives. Yager's procedure to determine the relative importance of the criteria is to calculate the eigenvector of the maximum eigenvalue of a matrix of paired comparisons; this is done according to the importance of one criterion over another, when only those two criteria are considered.

TABLE 1

SITE EVALUATION CRITERIA

- Groundwater
- Surface Water
- Air
- Soil
- Subsurface Gas Release
- Transportation Release
- Worker Practice

Case Study

To illustrate how Fuzzy Set Analysis may be used, consider the following hypothetical example. Hazwaste Disposal Company (HDC) owns and operates five commercial landfills. As a result of the RCRA requirement for exposure information, HDC submitted reports to the EPA for their consideration. However, HDC has also elected to further explore the nature of the risk at each of their five landfills. Because of limited time and money, HDC hopes to determine the nature of the risk at each site, prioritize the risks among sites, and then undertake a program of corrective action, if necessary.

Table 1 lists the site evaluation criteria, and Table 2 summarizes the parameters analyzed within each criterion. The numerical ratings shown in Table 3 are the result of extensive analysis performed by technical experts in their respective fields. In many instances, computer models were used to predict pollutant concentration levels at various receptor points in order to realistically compare sites.

TABLE 2

SUMMARY OF PARAMETERS FOR EACH EXPOSURE PATHWAY

AIR

Observed Releases
Waste Characteristics
Waste Volume
Demographic Distribution
Target Receptors
Land Use
Meteorology - Wind Speed and Dispersion
Waste Volume

GROUNDWATER

Observed Releases
Depth to Aquifer
Precipitation
Permeability
Physical State
Containment
Waste Characteristics
Water Well Use
Subsurface Soil Characteristics
Target Receptors

SURFACE WATER

Observed Releases
Terrain
Precipitation
Flooding
Distance to Surface Water
Physical State
Containment
Waste Characteristics
Waste Volume
Target Receptors
Surface Water Use
Ecosystems

SOIL

Observed Releases
Terrain
Permeability
Physical State
Containment
Waste Characteristics
Waste Volume
Area Land Use
Target Receptors

SUBSURFACE GAS

Observed Releases
Waste Characteristics
Waste Volume
Demographic Distribution
Target Receptors
Meteorology

TRANSPORTATION

Observed Accidents
Waste Characteristics
Waste Volume
Routes
Demographic Distribution
Target Receptors
Land Use
Transfers
Containment
Management Training Practices

WORKER

Observed Accidents
Waste Characteristics
Waste Volume
Accessibility
Containment
Target Receptors
Management Training Practices

TABLE 3

SUMMARY OF SITE RATINGS

Exposure Pathway	Willow Road Site	Broadfield Site	Osage Site	Weston Site	Fairfield Site
Air	.7	.8	.8	.6	.7
Groundwater	.6	.7	.5	.4	.6
Surface Water	.7	.7	.6	.5	.6
Soil	.9	.8	.9	.9	.9
Subsurface Gas	.7	.4	.6	.9	.8
Transportation	.6	.8	.8	.9	.6
Worker	.9	.9	.9	.9	.9
	5.1	5.1	5.1	5.1	5.1

To determine an average opinion of the relative importance value for each of the 7 criteria, 19 individuals were selected as a representative cross section of a typical community. Each individual was asked to relate his or her preferences in paired comparisons of the criteria. The eigenvector of the maximum eigenvalues for the matrix of paired comparisons was calculated, and the mean value for each criterion was used as an exponential weighting factor for the data listed in Table 3. By weighting the ratings for each site according to the the importance factors of the selection criteria, no single criterion may be considered more important than another when considering the merits of an individual site. Therefore, any criterion from a site may be compared to the same (or any other criterion for another site) on a numerical basis.

As an illustration, if we consider that the worst chain is the chain with the weakest link, then the same logic can apply to the site ranking. In other words, we will review only the lowest weighted values for each site, and rank them accordingly. The results of the combined analysis are presented in Table 4.

For the five sites, the corresponding decision values indicate that the "worst" site is Weston, followed by Fairfield, Willow Road, Osage, and Broadfield.

Apart from concluding the rank of each site, Fuzzy Set Analysis provides a quantitative representation of the community opinion of the order of importance of the criteria, regardless of the sites being considered. Based on the importance factors averaged from a cross section of the community, public concern would be ranked according to the order presented in Table 5.

TABLE 4

SUMMARY OF DECISION VALUES

Exposure Pathway	Willow Road Site	Broadfield Site	Osage Site	Weston Site	Fairfield Site
Air	.3599	.5277	.5277	.2314	.3599
Groundwater	.4537	.3759	.3422	.2423	.4537
Surface Water	.8532	.8532	.7967	.7346	.7967
Soil	.9031	.8059	.9031	.9031	.9031
Subsurface Gas	.8998	.7624	.8596	.9693	.9361
Transportation	.7142	.8632	.8632	.9329	.7142
Worker	.9771	.9771	.9771	.9771	.9771

TABLE 5

ORDER OF IMPORTANCE OF CRITERIA

CRITERION	IMPORTANCE FACTOR
AIR	2.865
GROUNDWATER	1.547
SOILS	0.967
TRANSPORTATION	0.659
SURFACE WATER	0.645
SUBSURFACE GAS	0.296
WORKER PRACTICE	0.220

SUMMARY

Fuzzy Set Analysis can be used not only to rank the various waste disposal sites in terms of risk, but also to focus on the key parameters that affect decision making. HDC can use this technique to focus on potential risks and also to prepare a strategy for site remediation.

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ON THE EVOLUTION OF RISK ASSESSMENT AND RISK MANAGEMENT AND THE FUTURE NEEDS

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Only a quarter century ago, health and ecological concerns were dealt with almost exclusively by experts -- scientists and technologists who relied upon their experience, intuition, judgment, empirical rules of thumb, and a sense of safe vs. unsafe.

Since then, advances in medicine, toxicology, related biological sciences, ecology and analytical chemistry have resulted in recognition of risk assessment as a multidisciplinary endeavor.

Concurrently, public expectations for health and environmental quality, as well as direct and indirect public participation, have increased. Thus, today risk management is multivalue oriented.

The case study of the arsenic smelter at Tacoma, Washington, not only illustrates the multidiscipline/multivalue nature of risk assessment and risk management, but also underscores the importance of communicating and understanding risks. Today's roles of hazard assessor, exposure assessor, risk analyst and risk manager, may in the future be augmented by the role of communicator. The need for improving the bases for risk assessment, risk management, and communication of risk information is well recognized by today's leaders in these professions. However, existing efforts in research, pilot programs, and think thanks are limited and fragmentary. It is proposed that significant progress can come in each of the three fields by a collective identification of action oriented programs

The papers presented in this session on the arsenic smelter in Tacoma provide a vivid, and rather comprehensive, portrayal of the state-of-the-art of the risk assessment and risk management processes as applied in contemporary society. My purpose as wrap-up speaker will be threefold: to briefly review how our U.S. society came to its present status of risk assessment and risk management; to characterize some important aspects of present analysis and policy making; and to suggest a few factors which will shape future policies and practices.

The Past is Prologue

Over the centuries, as societies have progressed from survival to affluent lifestyles, their concerns for risk have become more and more complex, sophisticated and varied. Food adulteration, water and food sanitation, particulates in air and drug efficacy were the major concerns from the mid-nineteenth to mid-twentieth century. (1) Many products of today -- pesticides, plastics, brake fluids, solvents, antibiotics, surfactants, glues, synthetic fibers and aerosol personal care aids, for example -- simply did not exist in 1945. (2) At that time only the experts and science fiction buffs envisioned nuclear power, interstate highway systems, television, electronics, the space age technologies and the medical practices of today.

The technological advances since 1945, however, have spurred great expectations in terms, not only of material goods and services, but also in the interests of health, ecological balances and environmental esthetics.

The controversies, debates and decisions over nuclear energy, automotive safety, worker health practices, the "chemical of the month," air, water and land pollution, all involved identification of new hazards (real or potential) and a ratcheting down of public norms of safety expectations.

Concurrent with these recent technological advances and the heightened sophistication of risk concerns, we have significantly increased our reliance on government for dealing with these health and environmental matters -- and our whole style of decisionmaking has shifted -- until about 1965 the relatively few regulatory officials were regarded as experts. The agencies were staffed largely with scientists, analysts, and technological engineers who relied up judgment to determine the safe or the unsafe; quasi-scientific rules of thumb such as empirical safety factors, augmented simple data bases and analogy to related phenomena and intuition. As issues became more complex, logic and decision-analysis decisionmakers and/or means of rationalization. A considerable body of literature emerged in the seventies dealing with federal analysis for decisionmaking.

The increasing role of government has drastically increased the complexity of our decision process. The numerous laws have decreased the flexibility of the decisionmaker. The Delaney Amendment to the Food, Drug and Cosmetic Act prescribes a way of managing the risks of carcinogens intentionally added to the food supply; the Clean Air Act prescribes a standard of protection for hazardous air pollutants, the Occupational Safety and Health Act prescribes standards to be based on feasibility. The congressional and political pressures have assumed a significant portion of the risk management function. Perhaps even more noteworthy has been the evolution of the public participation function in regulatory proceedings. (1) Self motivated, nonstakeholder individuals and groups have evolved, public hearings are prescribed by law, and stakeholders become advocates and adversaries.

The final aspect of our historical perspective which I would like to mention is the role of technology itself in increasing our ability to detect long-term or low-level hazard potentials.

Analytical chemistry permits the detection of substances at the part per billion, part per trillion, and even the part per quadrillion level. However, toxicology and the related biological sciences are relatively new, still largely empirical sciences without an underlying base of integrating theory. Epidemiology and exposure monitoring involve laborious studies. Consequently, our study of adverse health effects has focused on identification of possible risks and this capacity far exceeds our ability to elucidate and interpret the significance of the possibilities.

The case study of the arsenic smelter further illustrates the unfolding saga of society attempting to deal with risks. The smelter first became operational in 1890 to fulfill a raw material need and reflected the go-west and industrial revolution mentality of simply producing a product and having jobs. It is interesting that the first study of the health effects of arsenic was reported in the English literature about the same time that the Tacoma smelter was built. (3) Occupational health, particulate control, and finally chronic health evolved as concerns largely since 1945, coincident with advances in our science and understanding of health and environmental effects. The roles of EPA, OSHA, and state government certainly became significant since 1970. And more recently, public participation has been direct at the local level, and indirect through influence on formation of national policy on air regulations.

In summary, evolution of U.S. administrative procedures and congressional mandates during the past two decades has directed the regulatory agencies toward probabilistic statements of risk. However, much of the concurrent public and media discussion has been in terms of risk or no-risk with limited focus on the significance of low probabilities.

<u>The Present Status of Risk Assessment and Risk Management</u>

I wish to review several selected aspects of risk assessment and risk management in order to properly characterize our complex decision process. My points of emphasis are those which I believe set the stage for improvements in our processes.

1. Risk assessment is distinguishable from risk management. Today we utilize risk assessment and risk management as a framework for thinking about decisions. The National Academy of Sciences (NAS) highlighted this distinction in 1983. (4) I believe the distinction is an important one. Risk assessment involves the generation, collection and evaluation of scientific and factual information in order to characterize risk as objectively as possible. Risk management, in contrast, involves decisions in a broader context -- social, economic and risk values. The two but interactive. Figure 1 illustrates the interrelationship of risk assessment, laws and social values as inputs to a risk management

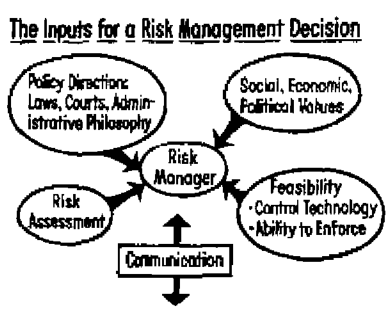

Figure 1

or by upper bound and lower bound estimates of risk. I'll hedge my views on the future by presenting three scenarios of the future but let you place your estimates on each scenario.

The first scenario involves a snail's pace evolution from the status quo by simply trying to refine and add on to our present approaches. The discipline of risk analysis will inch forward; more screening for hazards, empirical fitting of mathematical models to empirical data, improved peer review, and slow transfer of findings from molecular biology to risk assessment problems will be involved. Risk management will vacillate in its reliance upon the political process in contrast to the expertise and wisdom of science, engineering, and economics. But the trend will be toward innovative approaches such as unilateral corporate decisions to minimize risk, negotiation and resolution among stakeholders or at the community level, and administrative tribunals to lighten the loads on the courts.

The trend to an informed public will continue, but in a haphazard manner. Information availability, media sensationalism, communication and promotion by advocates, and the work of educators may well increase, but it will be capped by two factors -- the availability of resources and the public's ability to rely on common sense in terms of the relative weight to be given values and in their ability to decipher the relevant from the irrelevant.

In this muddled scenario of the future, perhaps the greatest progress will come from the enhanced ability to manage information provided by the computer systems. The ability to file information, to retrieve it, to analyze vertically, horizontally, and for specific criteria and properties are only now coming of age for the data bases used by risk analysts. These tools will provide new hypotheses and focus much more discussion on inconsistencies in estimates, logic paths and the messages of the communicator.

My second scenario includes the probability of discontinuities. First the topics of the risk agenda could change dramatically. Have the risk assessors of today analyzed the probability of oil from the Middle East being shut off for a six month period or a two year period? It seems that this year has seen a very noticeable increase in the number of air transportation fatalities and the damage from storms and earthquakes. Are these apparent increases random deviations, or flaws in our past statistical counting and estimating? Or, consider the plausibility of terrorists tinkering with our storage depots, communication and electrical switching points, or our water reservoirs.

On the optimistic side, it is plausible that significant breakthroughs will come in the biological sciences -- cancer researchers continue to be optimistic on finding cures or real prevention strategies; genetic engineers and investors have gleams in their eyes for new pharmaceuticals, safe pesticides and microorganisms that solve waste clean-up problems. The Health and Human Services Department has recently formulated a national policy which stresses problem solving in environmental health research; interpretation of problems might catch up with our rate of problem identification.

If any of the above events occurs, we will see a shift in our agenda of risks -- for the gloomy possibilities, many of today's low level risk debates will fade into oblivion. For the more optimistic breakthroughs, the scrutiny of new kinds of risk posed by the new technologies and societal activities would follow.

Incidentally, it would be interesting for analysts to compare the probabilities of occurrence of some of the above events with the probabilities for a few of today's concerns and to examine the relative proportion of national resources currently devoted to the different risk potentials.

My third scenario involves what I call a collective action agenda for improvement in risk assessment and risk management. It is based on the premise that we can collectively do much better than the fragmentary snail's pace scenario, and that a collective action plan will help society deal with the discontinuities of the future.

It seems to me that the needs for improving risk assessment, risk management and risk communication are well known and generally accepted. In the field of environmental health, three blue-ribbon reports of the past year articulate needs for research to improve the basis of risk assessment. The reports from a Task Force III group, from a panel of experts convened by the Council of Environmental Quality and the HHS Administration all articulate very similar needs. (6,7,8) These reports, however, stop short of defining an action plan or in defining programs that fit into results oriented institutional programs.

Similarly there is general dissatisfaction on our present approaches to risk management. Stewart, a Harvard law professor, recently pointed out the shortcomings of command and control regulations. (9) Congress is frustrated by the slow progress on waste site clean-up and in the time to write regulations. Clean Sites, Inc., a private sector enterprise was formed by industry and environmental groups to augment the government role in cleaning up waste sites. Mediation of environmental problems has occurred at the community level in recent years. Pilot programs to negotiate proposed rules are underway at OSHA and EPA. The Dubos Center will hold a workshop later this year to explore ways that the private sector can augment the government role in control of hazardous substances. All of these are embryonic attempts to make risk management more cost effective and timely. William Ruckelshaus has, on several recent occasions, emphasized the need to do analytical work and to synthesize new concepts for dealing with risk.

Finally, the emerging recognition that risk communication and education need investigation has already been stated.

As a generalization, the current approaches to all these need areas are largely fragmentary, single individual or single institution projects, often justified principally on the basis of other "more expedient" short-term goals.

My challenge is, instead of more conferences on the needs of risk assessment, management, or communication, we should organize workshops that focus on such questions as: Assuming a large yearly budget, what specific research programs should be initiated to improve the basis of risk assessment? The basis of risk management? The improvement of understanding of risk phenomena? Productive ideas for progress will come only if we change some of our meetings -- the topics must focus on the specifics of action programs, the participants must be those who generate new information and those which represent institutions who can deploy funds.

I believe we can make real progress in the quality of risk decisions and the utilization of our limited national resources if we develop action oriented programs -- research, pilot effort and policy concepts -- that explore and test the already largely defined needs. Collective agendas that incorporate and augment the current institutional efforts will catalyze interests and support. The alternative to real progress is the muddled snail's pace scenario and limited national capability to anticipate and plan for the discontinuities of the future.

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