United States
Environmental Protection
Agency

Office of the Administrator
Science Advisory Board
Washington DC 20460

SAB-EC-88-040E
September 1988
Final Report

EPA

Appendix E: Strategies for Risk Reduction Research

Report of the Subcommittee on Risk Reduction

Research Strategies Committee

NOTICE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Science Advisory Board
Research Strategies Committee
Risk Reduction Subcommittee

CHAIRMAN

Dr. Raymond Loehr
Chairman, 8.614 ECJ Hall
Civil Engineering Department
University of Texas, Austin, Texas 78712

MEMBERS/CONSULTANTS

Mr. Richard Conway
Corporate Development Fellow
Union Carbide Corporation
Post Office Box 8361 (770/342)
South Charleston, West Virginia 25303

Dr. Anthony Cortese
Tufts University
474 Boston Avenue
Curtis Hall
Center for Environmental Management
Medford, Massachusetts 02155

Dr. Anil Nerode
Cornell University
Department of Mathmatics
White Hall
Central Avenue
Ithaca, New York 14853-7901

Dr. Adel Sarofim
Massachusetts Institute of Technology
Building 66, Room 466
Cambridge, Massachusetts 02139

Dr. Paul Slovic
Decision Research
1201 Oak Street
Eugene, Oregon 97401

Mr. Roger Strelow
Vice-President
General Electric Company
3132 Easton Turnpike
Fairfield, Connecticut 06431

EXECUTIVE SECRETARY

Mrs. Kathleen W. Conway
Deputy Director
Science Advisory Board
U.S. Environmental Protection Agency
401 M Street, S.W., A101-F
Washington, D.C. 20460

STAFF SECRETARY

Mrs. Dorothy M. Clark
Staff Secretary
Science Advisory Board
U.S. Environmental Protection Agency
401 M Street, S.W., A101-F
Washington, D.C. 20460

TABLE OF CONTENTS

		PAGE
1.0	EXECUTIVE SUMMARY	1
1.1	Key Points in This Report	1
1.2	EPA Mission and Strategies	4
1.3	Risk Reduction Research Concepts	8
1.4	Risk Reduction Research Strategy	9
1.4.1	Hierarchy of Strategies	9
1.4.2	Continuum of Activities	11
1.5	Risk Reduction Research at EPA	11
1.6	Core Areas for Risk Reduction Research	15
1.6.1	Criteria for Selection	15
1.6.2	Core Areas for Research	15
1.6.3	Nature and Benefits of Core Areas	16
1.7	Implementation Strategies	16
1.7.1	Research Management Process	16
1.7.2	Education and Technology Transfer	19
1.8	Industry-Government-Academia Partnership	19

Table of Contents Continued

	PAGE
2.0 BACKGROUND INFORMATION AND DETAILS	21
2.1 Risk Reduction: A Central Goal of Environmental Research and Development	21
2.1.1 Risk Reduction Research and EPA's Mission	21
2.1.2 A New Environmental Policy	22
2.1.3 A Strategy for Risk Reduction Research	22
2.2 Defining Core Areas Within the Elements of Strategic Risk Reduction Research	23
2.2.1 Defining the Universe of Risk Reduction Techniques	24
2.2.2 Preventing Waste and Contaminant Generation	25
2.2.3 Recycling and Reuse	26
2.2.4 Treatment and Control	27
2.2.5 Reducing Exposure After Optimum Pollution Prevention, Treatment and Control	31
2.2.6 Selecting Risk Reduction Strategies	34
2.2.7 Incentives for Risk Reduction	38
2.3 Education and Technology Transfer	39
2.3.1 Education and Training Programs	40
2.3.2 Technology Transfer	41
2.4 Implementation Strategies for Risk Reduction Research	43
2.4.1 An Orientation to Solving Problems	43
2.4.2 Establishing and Updating Priorities for Risk Reduction	44
2.4.3 Extramural and Intramural Research	50

APPENDIX A: Memorandum of December 10, 1987 Entitled "Economic Successes in Risk Reduction Research"

APPENDIX B: References

APPENDIX C: Areas of Strategic Risk Reduction R and D

LIST OF FIGURES AND TABLES

		PAGE
FIGURE 1:	Elements of an Environmental Research Strategy	2
FIGURE 2:	Risk Assessment/Risk Management Paradigm	2
FIGURE 3:	Continuum of Components for Strategic Risk Reduction Research	5
FIGURE 4:	Example Involvements of Research Strategy Council and Core Area Workshops in Risk Reduction Research Planning and Implementation	7
FIGURE 5:	Hierarchy for Risk Reduction Research	10
FIGURE 6:	Fundamental Research Applies to Environmental Risk Reduction	17
FIGURE 7:	Education and Technology Transfer are Important to the Reduction of Risks to Human Health and the Environment	20
TABLE 1:	Example Risk Reduction Activities	6
TABLE 2:	Examples of Benefits	13
TABLE 3:	Value of Benefits	14

1.0 EXECUTIVE SUMMARY

In 1987 the Science Advisory Board formed a Research Strategies Committee to develop a strategy for environmental research and development. At its first meeting on September 10-11, 1987 the Committee identified five elements of the strategy: sources; transport and fate; exposure; environmental effects; health effects; and risk reduction as illustrated in Figure 1 on page 2. The Risk Reduction Subcommittee met October 12, November 24, and December 17, 1987 and March 16, 1988. The Risk Reduction Subcommittee prepared the strategy which follows for the Research Strategies Committee. In terms of the National Academy of Sciences Risk Assessment/Risk Management paradigm, familiar to many EPA employees and illustrated in Figure 2 on page 2, risk reduction includes both control options and some aspects of non-risk analysis.

1.1 Key Points In This Report

The discussions and considerations of the Risk Reduction Subcommittee are contained in this report. The important points and recommendations that resulted from those considerations follow.

1. Risk reduction, the central goal of EPA, should also be the central goal of research and development at EPA.

2. Risk reduction research, of the type defined in this report, is appropriate for EPA and is not likely to be undertaken by or to duplicate research by the private sector.

3. Risk Reduction techniques include both technology-based strategies and other strategies (such as those in Table 1 on page 6) involving disciplines other than the physical and biological sciences and engineering. EPA's research program should address all appropriate risk reduction strategies with systematic, rigorous development and evaluation including peer review.

4. EPA should take a leadership role, broadly construing its legislative mandates, in solving problems affecting human health and the environment.

5. EPA should base its activities on a policy that has the following hierarchy of risk reduction strategies. These should apply to all environmental media:

   a. preventing the generation of wastes, residues and contaminants,

   b. recycling and reuse,

Figure 1: Elements of an Environmental Research Strategy

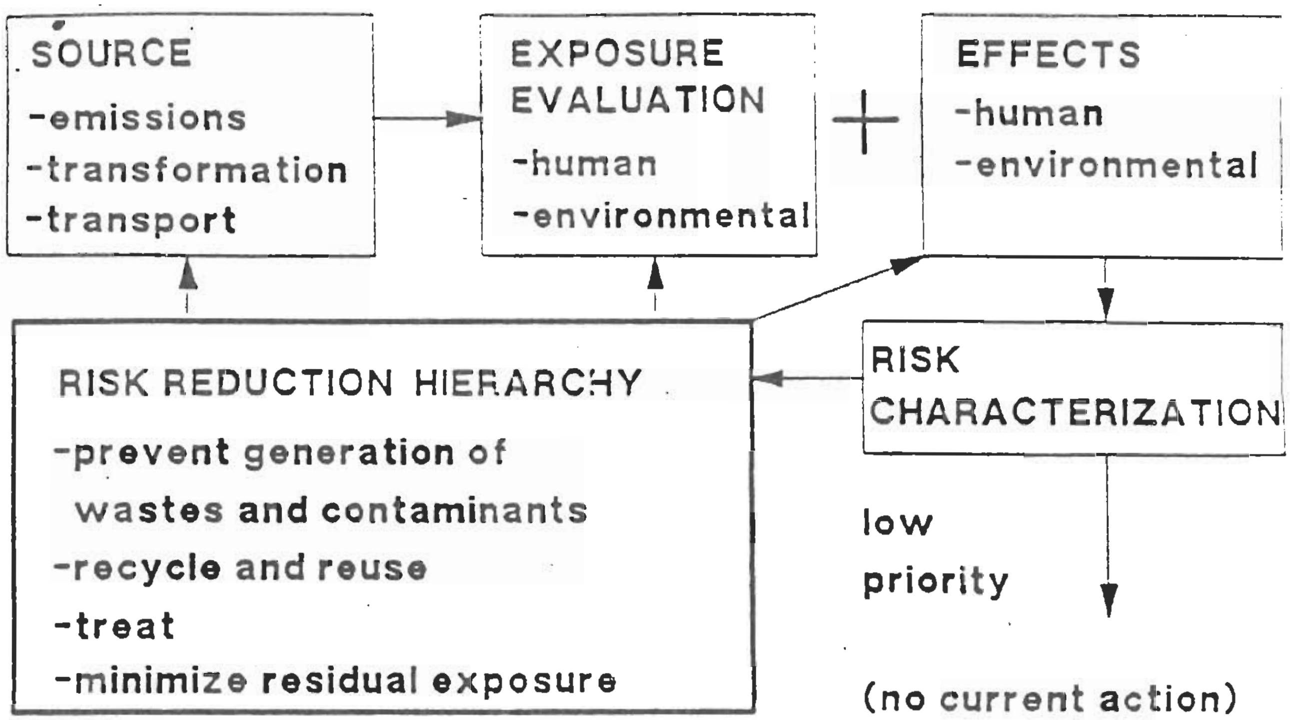
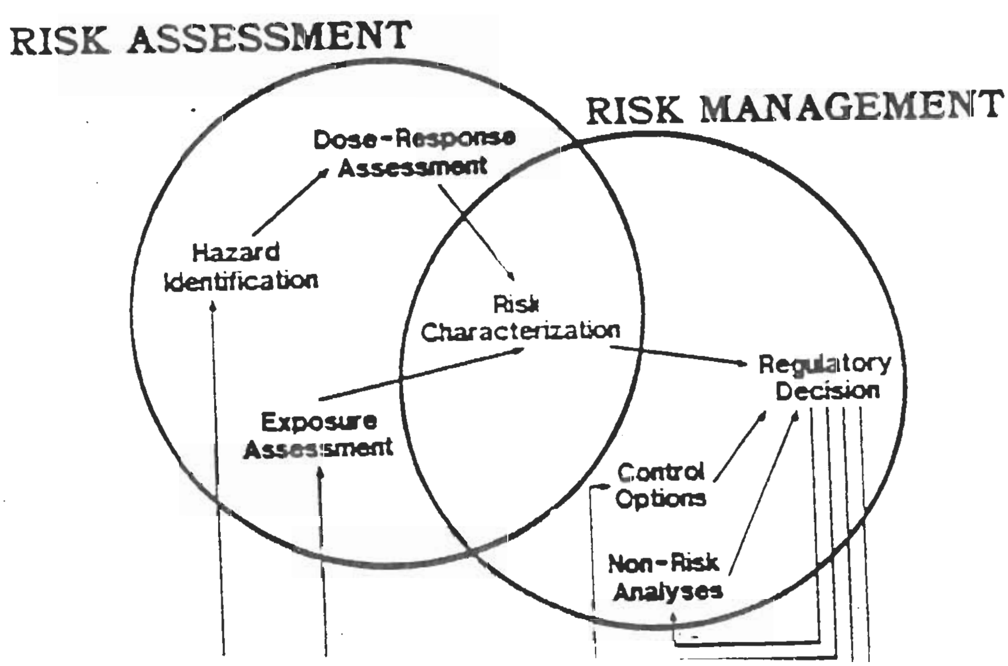


Figure 2: Risk Assessment/Risk Management Paradigm



c. treatment and control techniques, and

d. minimizing residual exposure (containment, exposure avoidance).

6. The research programs in important areas such as source emissions, transport, fate, human and environmental exposure evaluation and effects, and risk assessment, should be designed to contribute effectively to the ultimate goal of risk reduction. (see Figure 1 on page 2)

7. EPA in consultation with others, should identify core areas of continuing risk reduction research using criteria presented in this report. These core areas would support broad comprehensive needs of EPA and would be critically reviewed periodically.

   Examples of initial or candidate core risk reduction research areas are:

   a. preventing pollutant generation,
   b. combustion and thermal destruction,
   c. separation technologies,
   d. biological approaches for detoxification and degradation,
   e. chemical treatment of concentrated wastes and residues,
   f. ultimate containment methods and approaches,
   g. exposure avoidance,
   h. risk communication and perception,
   i. incentives for risk reduction,
   j. education and technology transfer, and
   k. environmental management and control systems.

8. EPA should develop strong scientific programs in each core area, provide facilities and incentives to attract top researchers to run these programs and maintain the stability of funding needed to nurture scientific leadership in these areas.

9. Education and technology transfer are essential to achieve risk reduction goals and are thus legitimate and important activities of EPA and, particularly of the Office of Research and Development.

10. EPA should plan and conduct risk reduction research in partnership with industry and academia.

11. An EPA risk reduction research strategy should recognize that there is a continuum of activities (Figure 3 on page 5 and Table 1 on page 6) that individuals, groups and institutions can engage in to reduce health and environmental risks. EPA should design a comprehensive research strategy as recommended here based on capacity for risk reduction, without regard to distinctions of discipline, long vs. short-term, pure vs. applied, or scientific vs. engineering. Understanding where in

the continuum of activities it is appropriate to utilize resources to reduce risk is a key component of a risk reduction research strategy. The first step, however, is to recognize that there is a continuum of activities that make up an overall risk reduction research strategy (Figure 3 on page 5).

12. A new process for implementation of risk reduction research programs is essential. This process should ensure that the most important present and future risk reduction issues and problems are acted upon and that research outputs are relevant and support program office risk reduction goals. The process depicted in Figure 4 on page 7 would include:

    a. Expanding the function of EPA research committees to include all the elements of risk reduction research programs contained in this report,

    b. Mechanisms for active involvement of the external scientific community and affected groups in defining core areas of research and programs within these areas. One mechanism is the use of periodic workshops convened by the SAB involving ORD, program offices and the community outside EPA, and

    c. A Research Strategy Council consisting of senior administrators and career executives throughout EPA to ensure that this process results in the most effective risk reduction programs.

1.2 EPA Mission And Strategies

Prior to discussing an appropriate risk reduction research strategy for the U. S. Environmental Protection Agency (EPA), it is necessary to identify the basic mission of EPA. The mission transcends the specific requirements of individual laws and provides the focus for all of the activities in EPA, including research and development.

EPA's basic mission is to reduce the level of risk to health and to the environment posed by wastes, residues and contaminants. In carrying out that mission, EPA must carry out the programs mandated by law as a first priority. However, state and local government, industry, the general public, as well as people and institutions in other nations view EPA as a world leader in all pollution caused problems affecting public health and the environment. Viewed in this context EPA must provide leadership on scientific and policy issues involved in environmental protection and must balance environmental goals with other societal goals.

In the past, EPA has largely focused on specific programs mandated by Congress. More recently, EPA has assumed a broader leadership role by sponsoring research on global problems, including stratospheric ozone depletion and indoor air pollution problems such as radon contamination.

Figure 3: Continuum of Components for Strategic Risk Reduction Research

Strategic Risk Reduction Research contains many inter-related components. Each concern or problem requires a different set of activities and outputs to reduce specific risks to human health and the environment.

Table 1: Example Risk Reduction Activities[1]

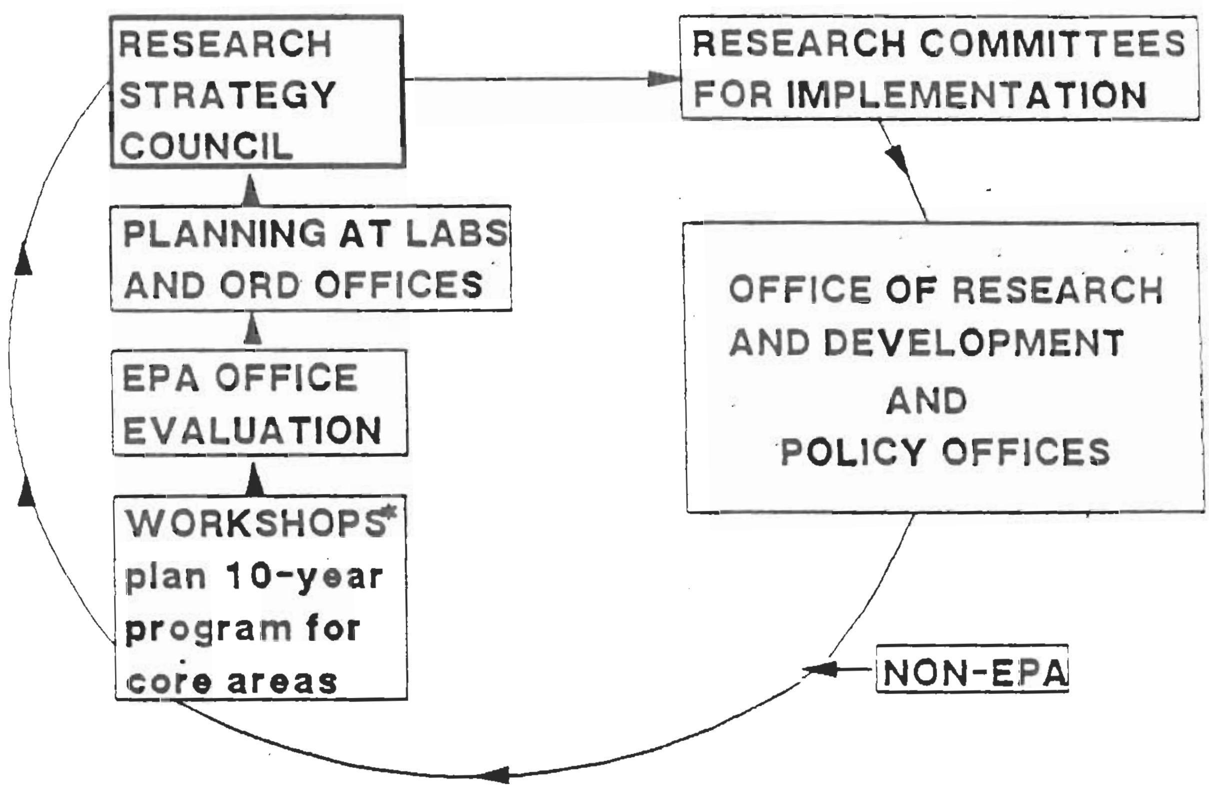
	INDIVIDUALS	GROUPS[2]	INDUSTRY	OTHER INSTITUTIONS[3]
PREVENTING POLLUTANT GENERATION	Energy and water conservation Purchase non-hazardous household products Organic gardening	Car pooling Integrated pest management Land acquisition for environmental protection	Raw material substitution Process redesign Product redesign	Purchase of biodegradable products Purchase of recycled products Zoning to protect critical resources
RECYCLING AND REUSE	Reuse of paint cleaners Trade in used car batteries Donate unused paint to school art department	Community solid waste recycling Oil recycling Community hazardous waste recycling	Solvent reclamation Use of scrap iron in steel making Kraft process for chemical and energy recovery in pulp making	Paper recycling Commercial glass recycling Use composted yard waste for fertilizer
TREATMENT AND CONTROL	Asbestos removal Auto inspection and maintenance Heating system maintenance	Water supply treatment Community composting Landfill wood chipping	Solid and hazardous waste incineration Air pollution control devices Accident prevention programs	Co-composting sludge and solid waste Wastewater treatment Chemical inventory, audit and control systems
REDUCE RESIDUAL EXPOSURE	Home ventilation for radon, gas stoves Home water filtration devices Don't fish in polluted waters	Proper sanitary landfill Land use planning Household hazardous waste collection	Secure chemical landfill Pollutant dispersion technologies Controlled pesticide application	Smoke free work areas Proper building ventilation Purchase bottled water

1. Many of these strategies, e.g., energy conservation, can be employed by all

2. Communities, community groups

3. Federal and state government, academia, health care institutions, commercial business, etc.

Figure 4: Example Involvements of Research Strategy Council and Core Area Workshops in Risk Reduction Planning and Implementation



*Non-EPA chair of workshops to advise on whether the key items from the workshops get to the Research Strategy Council

The EPA research and development strategy should focus on problems and areas where there is the greatest potential for reducing risk to human health and the environment. This strategy will allow EPA to prevent or control wastes, residues and contaminants as efficiently as possible while focusing the limited resources of EPA on situations where these items cause the greatest impact and where the greatest reduction of risk can be accomplished.

It is clear that risk reduction is a critical aspect of the EPA mission and can serve as an overall coordinating strategy. Research and development must support the risk reduction role of the Agency. Soundly conceived and properly managed, an EPA risk reduction strategy would use all available information and studies within and outside EPA to:

a. identify the scientific and technical approaches that have the greatest opportunity for reduction of risk to human health and the environment,

b. prioritize these approaches on the basis of relative risk reduction,

c. provide the logic for resource allocation that is consistent with relative risk reduction, and

d. provide a sound basis for regulations.

1.3 Risk Reduction Research Concepts

Research at EPA can be considered as:

a. supporting the specific programs and priorities of the regulators, or and

b. more broadly supporting the basic objectives of the statutes from which the regulatory programs are derived.

Research that is limited entirely to direct support of current regulatory programs and priorities may fail to accomplish maximum feasible risk reduction. Current regulatory activity may not always be focused on the highest risk associated with the pollutants or activities in question. Rather, such activity may merely fill gaps in regulations adopted years earlier. In addition, control of some risks either is not yet, or perhaps cannot be, dealt with primarily through regulations.

Risk reduction research cannot ignore the needs of ongoing regulatory programs; however, it should address the needs in a broader, more comprehensive framework. The total research program helps to reduce environmental risks in complementary ways:

a. by supporting and facilitating implementation of regulations aimed at reducing risk,

b. by defining the risk at issue and/or developing technology needed to comply with risk-prevention rules, and

c. by demonstrating the feasibility of risk reduction actions that, although consistent with regulatory requirements, may be undertaken independently of regulations.

Therefore, an appropriate research and development program directly reflects and supports the Agency's risk reduction strategy. Specifically, planning as described in Figure 4 would determine what research and development activities are needed to reduce the risk to human health and the environment posed by wastes, residues and contaminants. Such planning would also indicate the proper timing of that research and development. Most importantly, by identifying the extent to which the research (if successful) will reduce risks to human health and the environment, such a program provides clear and firm logic for EPA research and development activities. This facilitates the balancing of competing research needs. Provision of information to state and local government and to the public can accomplish risk reduction goals; education and technology transfer, therefore, has an important place in the research strategy.

1.4 Risk Reduction Strategy

1.4.1 Hierarchy of Strategies -- EPA should develop a national environmental protection policy based upon preventing environmental pollution and thereby reduce risks as early as possible. This policy can be described as a hierarchy of strategies (Figure 5 on page 10) for risk reduction consisting of: preventing the generation of wastes and contaminants, recycle/reuse, treatment, and minimizing exposure through containment, and avoidance (for further illustrative examples, see Table 1 on page 6). As noted above, the EPA research program should also reflect this same hierarchy of strategies.

a. Preventing Waste and Contaminant Generation - The most effective strategy to reduce risk to human health and the environment is to prevent the production of waste and contaminants. Such a strategy eliminates potential environmental problems,

   Example: Substitution of water-based paint for solvent-based paint in automaking

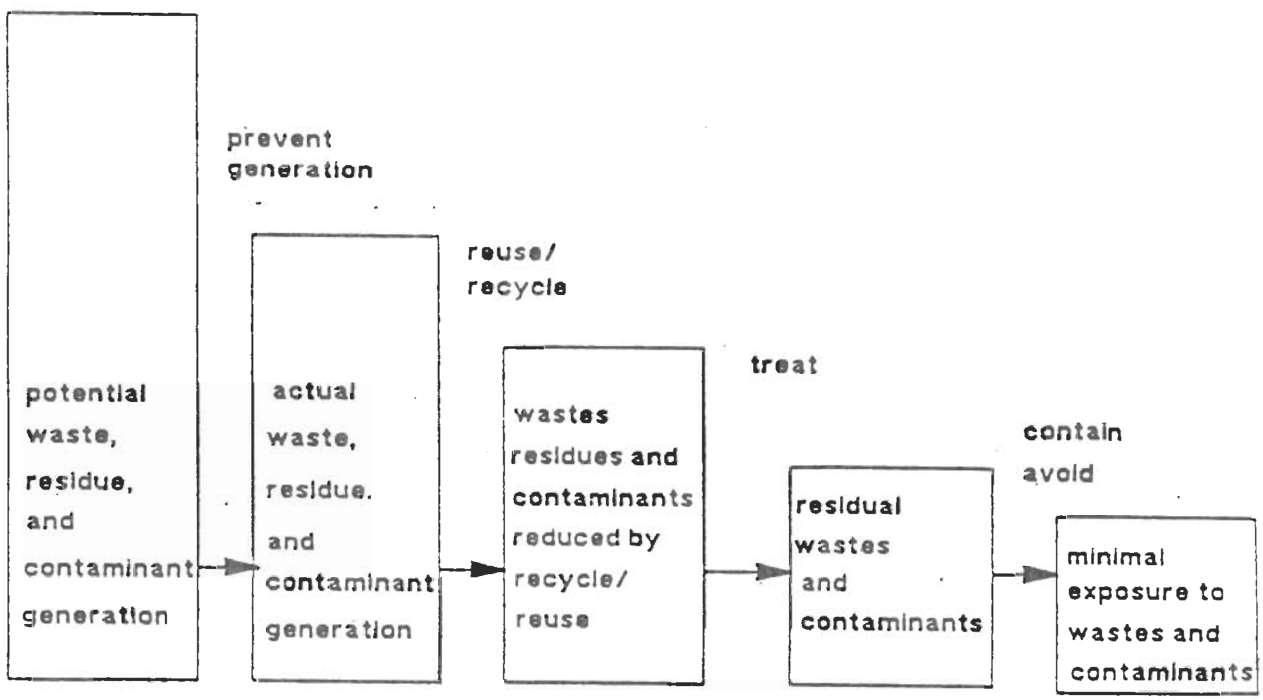
b. Recycling and Reuse - Strategies to recycle and reuse wastes and contaminants can eliminate their release to the environment thereby avoiding the need for treatment or disposal,

   Example: Recycling waste oil

c. Destruction, Treatment and Control: Strategies to destroy, treat, detoxify or control environmental contaminants in order to eliminate or minimize their release should be employed for all wastes which cannot be eliminated or recycled, and

   Example: Incineration of hazardous wastes

Figure 5: Hierarchy for Risk Reduction Research



d. Minimization of Residual Exposure - Once the generation of wastes and contaminants has been reduced and the release of the wastes and remaining wastes and contaminants has been controlled to the optimum extent, any remaining risk must be addressed by avoiding or minimizing exposure.

Example: Building ventilation

While risk reduction research must focus on all of these major areas; source control, source reduction and recycling should receive greater emphasis to reduce to a minimum those waste streams and contaminants that require treatment and ultimate disposal. Research on environmentally sound and cost-effective methods of treatment and disposal also must continue since there will always be wastewaters, sludges and residues that require sound treatment and disposal. Research on other methods of exposure avoidance should be initiated.

1.4.2 Continuum of Activities -- A risk reduction strategy must recognize that the possible risk reduction approaches are all part of continuum of activities (Figure 3 on page 5). Many terms are frequently used to identify the various aspects of this continuum. However, terms such as research, development, demonstration and technology transfer are artifical distinctions and separations. Research and development programs for risk reduction must be based on what will best reduce risk, and should not be limited by artifical or traditional distinctions. Adhering to this principle will greatly enhance the perception of EPA by all interested parties, Congress, the public, and EPA's own staff. The radon program is an example of a well-regarded non-regulatory program for risk reduction.

Not all environmental problems require effort all along the continuum. Where pertinent knowledge exists but is not widely known or disseminated, educational and technology transfer efforts may be the most appropriate stategies. For technologies and management approaches that appear technically and economically feasible, large-scale demonstration efforts may be most appropriate. In some situations, fundamental scientific and technical knowledge must be broadened before the extent of a problem and better solutions are identified. The time required for these efforts can vary depending on the available knowledge base and the success in obtaining and utilizing more pertinent information.

Understanding where in the continuum of activities it is appropriate to utilize resources to reduce risk is a key aspect in implementing of a risk reduction research strategy.

1.5 Risk Reduction Research at EPA

The question of whether the private sector, and not EPA, should fund and be responsible for control technology development is frequently asked.

Risk reduction strategies encompass much more than treatment technology (see Figure 5 on page 10 and Table 1 on page 6). Risk reduction research includes research on all of the topics noted in the hierarchy shown in Figure 5 on page 10.

The private sector is unlikely to take responsibility for risk reduction research efforts (2, 3, 4). For several reasons, EPA must perform risk reduction research if the nation is to achieve its environmental goals. Research and development is in part a "public good" as evidenced by studies which demonstrate that many successful innovations come from ideas generated outside the firm which develops the innovation. There are also insufficient economic incentives for the private sector to perform basic risk reduction research. Such research has a low chance of commercial success. Short deadlines for compliance with regulations encourage the use of existing technology. No one company or industry is likely to have a unique, important stake in many environmental issues, thus making individual action hard to justify to management or investors. Industry is not monolithic; there are so many sectors involved that they will not get together to sponsor generic research. The industrial sector has little economic incentive to develop technologies which significantly reduce the emissions of pollutants to below regulatory levels, knowing that such technology may result in lower emission standards for all industry. In addition, most pollution control companies do not have the financial strength to devote significant resources to research and development. Moreover, municipal wastewater and drinking water treatment are most often performed by municipal governments which can hardly afford existing technology and have traditionally invested very little in research and development. Finally, EPA risk reduction research can provide large economic, health and environmental returns. Recent studies by EPA indicate that successful risk reduction technologies developed by EPA have saved the nation from $30 to over $1,000 for every dollar spent by EPA. See Tables 2 and 3, pages 13 and 14.

Other agencies such as the National Science Foundation, Department of Energy, Department of Defense, and the Department of Health and Human Services could conduct risk reduction research. However, the charters for these agencies are not the same as for EPA. Although these agencies support research which is technically and scientifically sound, it is unlikely that such research would obtain the type of data needed by EPA to make regulatory decisions or provide the research results in a timely fashion to focus directly on and meet the EPA needs. Divorcing research needed for risk reduction from the regulatory decision making process would breed inefficiency and frustration and likely would result in regulatory decisions being made on incomplete knowledge.

EPA needs to conduct risk reduction research to assure the Agency's credibility. EPA is the agency charged with protection of human health and the environment. EPA is expected to be and needs to be the "authority" in the broad area of environmental risk reduction. Therefore, it is imperative that EPA have a strong risk reduction research strategy and adequate resources to implement that strategy.

Table 2: Examples of Benefits

EPA's Office of Research and Development has supported research on technologies which have improved treatment effectiveness, reduced risk, and resulted in savings of energy and costs. Successful technologies include:

For Wastewater Treatment

trickling filter/solids contact process which achieved suspended solids and BOD of 10 mg/l without effluent filtration

secondary clarifiers with flocculator center wells which produced average effluent suspended solids and BOD of 5 mg/l

top-feed vaccum filtration for sludge dewatering which yielded higher cake solids than bottom-feed vacuum filters

For Hazardous Wastes

a Superfund Innovative Technology Evaluation (SITE) of infrared incineration used for the decontamination of soils

on-site treatment for liquid wastes contaminated with dioxins and furans using potassium polyethylene glycolate (called the APEG on KPEG process).

microbial treatment for both in situ and on site treatment

See Appendix A for details.

Table 3: Value of Benefits

Technology	Expenditure for Research	National Cost Savings	Benefit-to-cost Ratio
Secondary Clarifiers with Flocculator Center Wells	$ 70 000	$ 380 000 000	1400 to 1
Trickling Filter/ Solids Contact Process	$ 290 000	$ 280 000 000	1000 to 1
Oxygen Aeration	$ 3 200 000	$ 14 000 000	3.3 to 1
APEG Treatment	$ 212 000	$ 3 100 000	10 to 1

See Appendix A for details

In summary, the suggestion that private industry or other agencies will undertake the risk reduction research needed to protect the nation if EPA does not, is fiction. Protection of human health and the environment is a public good, and a public agency should have lead responsibility for and undertake risk reduction research, development and demonstration. The basic mission of EPA is to reduce the level of risk to human health and the environment. Therefore, it is appropriate for EPA to have a significant and serious health and environmental risk reduction research effort.

1.6 Core Areas for Risk Reduction Research

Certain types of pollutants have a large impact on human health and the environment and thefore require continuing attention and new technical approaches. Risk reduction research in EPA should be organized by core areas.

1.6.1 Criteria for Selection -- Selection of core areas should be guided by the following criteria:

a. problems of high risk that can be expected to persist for a decade or more,

b. areas in which generic research can support a number of existing and anticipated EPA and state programs,

c. areas in which inadequate information exists for sound regulatory decisions and guidance, and

d. areas where research is unlikely to be conducted by others.

1.6.2 Core Areas for Research - Examples of initial or candidate core risk reduction research areas are:

a. preventing pollutant generation,
b. combustion and thermal destruction,
c. separation technologies,
d. biological approaches for detoxification and degradation,
e. chemical treatment of concentrated wastes and residues,
f. ultimate containment methods and approaches,
g. exposure avoidance,
h. risk communication and perception, and
i. incentives for risk reduction.

Other research strategy group reports discuss additional potential core areas which can contribute to risk reduction. The development of test methods and the conduct of risk assessments, for example, may support the risk reduction effort.

1.6.3 Nature and Benefits of Core Areas -- Risk reduction research in each core area ultimately may include the full continuum of activities illustrated by Figure 3 on page 5. The challenge for EPA is to determine at what point in the continuum to utilize available resources in each of these core areas. Research in each of these areas also should focus on:

a. minimizing cross-media transfer of contaminants,

b. clarifying the technical and scientific fundamentals (see Figure 6 on page 17), and

c. identifying the economics of feasible source reduction, recycling, treatment and disposal options.

Risk reduction research addresses the needs of ongoing regulatory programs in a broader, more comprehensive framework. Core areas focus on those problems whose solutions require an on-going research program which will support both current and future Agency programs aimed at reducing risks to human health and the environment.

Strength in the core areas benefits the program offices by placing EPA in a sound position to develop guidance and approaches for problems that place human health and the environment at risk. Investing in risk reduction research reduces current and future risks to human health and the environment, thereby increasing the quality of life and productivity. Such research is an investment that protects not only present but also future generations.

If the world were ideal, a risk reduction strategy could focus primarily on the concerns and problems that are arising. However, a realistic strategy must address simultaneously diverse problems that have resulted from past and current activities:

a. residues from past actions such as abandoned sites and contaminated groundwater,

b. currently generated wastes and residues that are affecting soil, air and water and are modifying ecosystems, and

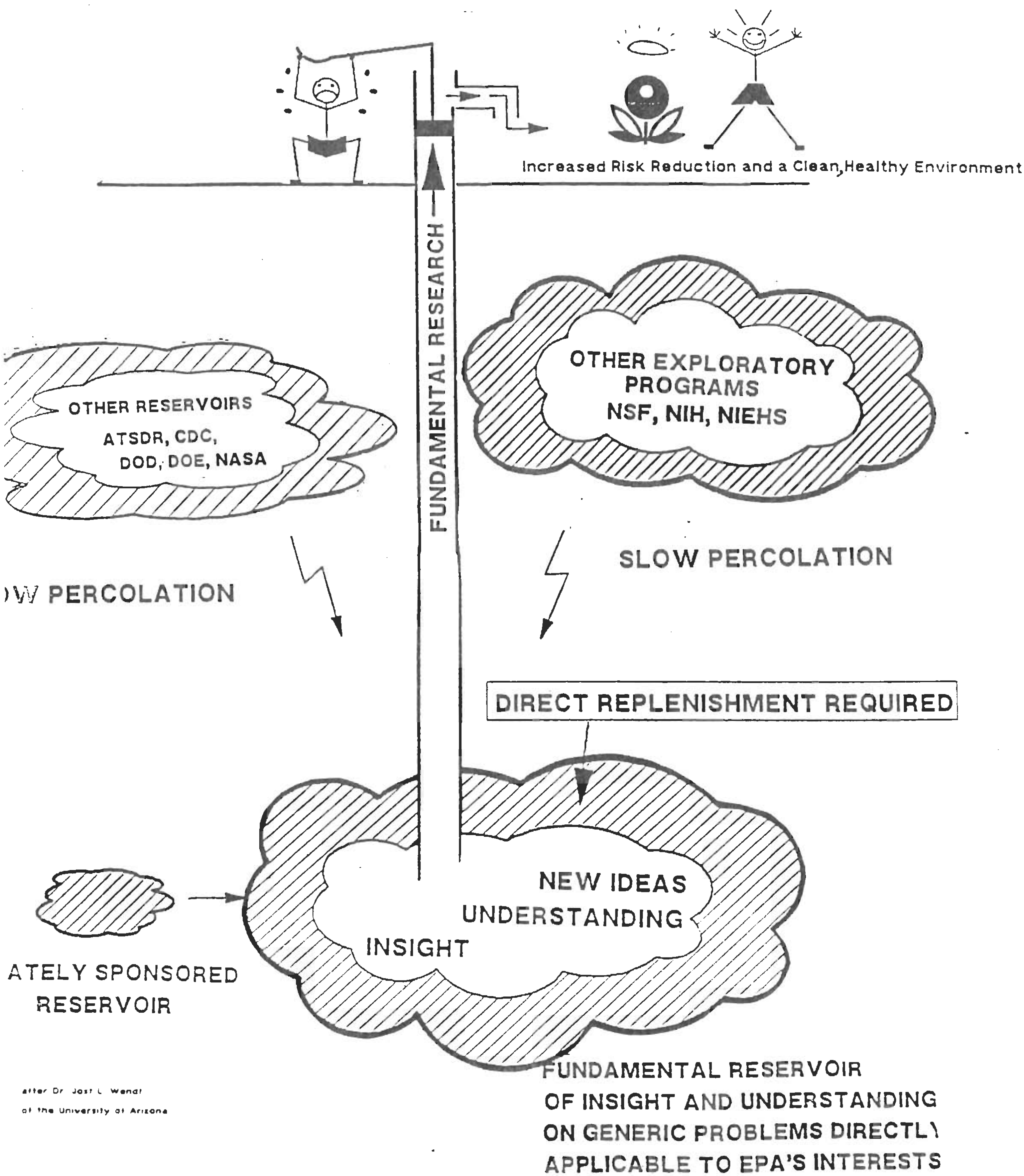
c. control of activities such as release of chlorofluorocarbons (CFCs) that increase the future risks to human health and the environment.

Risk reduction research in the noted core areas can address these diverse problems.

1.7 Implementation Strategies

1.7.1 Research Management Process - EPA needs a new research management process for risk reduction research to ensure that: (a) the most important present and future risk reduction issues and problems are acted upon, (b) research outputs are relevant and (c) the research supports program office risk reduction goals. The new process, depicted by Figure 4 on page 7,

Figure 6: Fundamental Research Applies to Environmental Risk Reduction



after Dr. Jost L. Wendt
of the University of Arizona

would expand the role of the existing research committees to include all the elements of risk reduction research programs. The jurisdiction of the research committees would include some elements which have not been high priorities or a traditional part of the ORD mission, (e.g., chemical accident prevention strategies, risk communication).

The process would also involve mechanisms for periodic active involvement of the external scientific community and other affected and interested groups in defining core areas of research and programs within these research areas. One such mechanism of involvement is the use of periodic workshops convened by the SAB involving ORD, program offices and the community outside EPA. Such mechanisms can give EPA access to additional expertise which will assist the agency in targeting the research efforts to the most important problems and can build external support for its research effort. The proposed workshops will recommend the relative resources that should be allocated to core areas and the appropriate administrative structures for carrying out the research. These workshops probably will redefine the core areas.

A Research Strategy Council consisting of senior administrators and career executives from all major EPA programs would oversee the process to provide a continuing, high level management mechanism for the scope and direction of risk reduction research. The Council would focus on the cross-cutting issues that need attention and on how to structure approaches that would assure that adequate resources would be available for the designated core areas. The purpose of the Council would be to elevate the shaping of each year's research program above the level of simply responding to separate and perhaps uncoordinated regulatory or program office demands.

The Council would assure that adequate vision and support is provided to:

a. identify broad problems areas of high risk that are characterized by a lack of scientific understanding,

b. address problems in ways that generate timely research results for decision-makers,

c. assemble and retain a qualified group of scientists, engineers and other researchers, and

d. forecast new and escalating problems which will require research and development efforts.

The Council would meet once or twice annually to review past efforts and focus on major policy issues involving risk reduction programs which require significant continuing research efforts. Such a body would also provide a structured mechanism for high level input from research administrators into the Agency's other programs.

The outside scientific community can develop and articulate technical consensus opinions on a variety of issues for EPA to use in managing research. One mechanism for the development of technical consensus is workshops as illustrated in Figure 4 on page 7.

Problems for such workshops to address can be predicted in ways analogous to those used for technological forecasting (16):

a. intuitive forecasting either by a committee of experts or by a Delphi technique of separately and iteratively polling experts,

b. scenarios, or rich descriptions of assumed future conditions; these are useful in looking at possibilities not defensible with traditional logic and can examine extremes, and

c. monitoring or searching for signals of new concerns and for better approaches to reduce or eliminate current and future concerns.

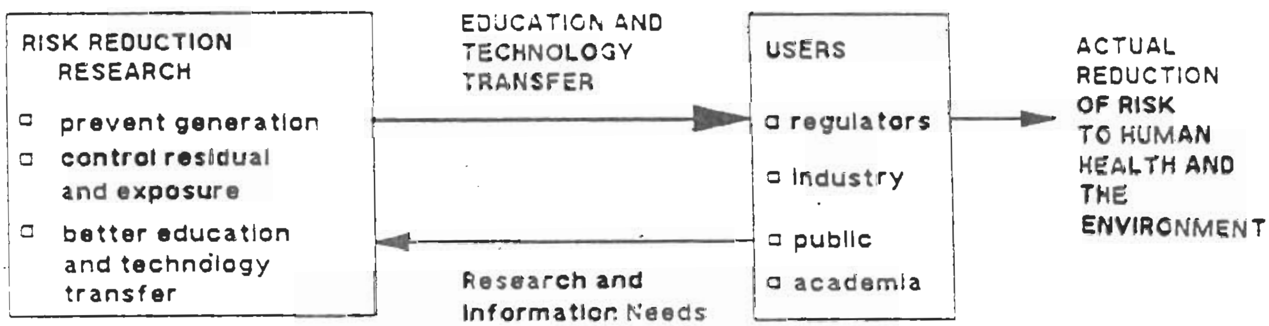
1.7.2 <u>Education and Technology Transfer</u> -- One of the greatest difficulties in a risk reduction strategy is getting pertinent information to the institutions, organizations and people who can use it. This is a particular problem for small and medium sized industries, for state and local governments and for consultants and design engineers. These groups and individuals look to EPA for the needed expertise and knowledge. The current EPA mechanism for education and technology transfer is an *ad hoc* system of individual contacts and occasional seminars, training courses and conferences.

Education and technology transfer is a legitimate function of EPA and of research and development at EPA. Private industry, academia and EPA should work cooperatively to provide the education and technology transfer to assure that the risk reduction research information is adequately disseminated and used (Figure 7, page 20).

1.8 <u>Industry-Government-Academia Partnership</u> -- It is important that EPA include other sources of expertise as part of its risk reduction strategy. Researchers outside EPA have much to bring to the endeavor that EPA often cannot duplicate internally. EPA must lead a broad-based, multi-party risk reduction research effort. For example, a risk reduction research partnership that includes industry is critical for source control, source reduction and recycling studies. Such studies can involve research on process redesign, product substitution and control technology.

There should be a strong extramural risk reduction research program to complement the EPA intramural risk reduction research program. This is important to encourage fresh interdisciplinary ideas and to make best use of the talent that exists in the nation. The partnership can consist of support for studies, technology transfer, use of facilities, joint use of personnel and training. Investigator initiated research should be a significant component of the effort.

Figure 7: Education and Technology Transfer are Important to the Reduction of Risks to Human Health and the Environment



2.0 BACKGROUND INFORMATION AND DETAILS

2.1 Risk Reduction: A Central Goal of Environmental Research and Development

2.1.1 Risk Reduction Research and EPA's Mission - EPA's basic mission is to reduce the level of risk to human health and to the environment posed by waste, residues and contaminants. In carrying out that mission EPA must carry out the programs mandated by law as a first priority. However, EPA is also viewed by state and local government, industry, the general public and by people and institutions in other nations as a world leader in all pollution caused problems affecting public health and the environment. In this context EPA is viewed as an organization which must provide leadership on scientific and policy issues involved in environmental protection and must balance environmental goals with other societal goals. A major responsibility in carrying out this mission is to provide information to state and local government, industry and the public about risk reduction strategies that will achieve human health and environmental goals. Further, EPA is expected to develop and evaluate risk reduction strategies in the legal, scientific, political, cultural and social context in which it operates.

In the past, EPA's work on developing risk reduction strategies has largely addressed the specific programs mandated by Congress. More recently, EPA has assumed a broader leadership role by sponsoring research on global problems including stratospheric ozone depletion and indoor air pollution problems such as radon contamination. However, EPA's research effort has been focused on cleaning up existing pollution problems with primary emphasis on pollution control technology. Moreover, the risk reduction work has been oriented to problems in specific environmental media such as control of water pollution control rather than generic research oriented toward minimizing problems across environmental media.

The orientation of EPA's risk reduction research is a result of the Agency following the narrow statutory mandates with tight deadlines for applying risk reduction strategies. These statutory mandates use a command and control regulatory approach designed to meet environmental quality standards as a means of rectifying existing environmental problems. Very little effort is expended on waste, residue and contaminant prevention across all environmental media, the most effective means of future risk reduction. This is not surprising. The EPA risk reduction research program is a microcosm of the way in which society has approached environmental protection problems. Pollution control has been reduced to a kind of programmed thinking and a way of shaping questions and answers about environmental management. As stated by Joel Hirschhorn of the Office of Technology Assessment, "the entrenched, rigidly adhered to, and unquestioned perception of pollution control as the way to achieve environmental protection defines the paradigm and undermines pollution prevention." (15)

In addition to not fostering waste, residue and contaminant prevention, the pollution control strategy has become extremely expensive and caused intermedia environmental problems, e.g., scrubbers which reduce air pollution create a noxious sludge for land disposal. In addition, the current strategy has not achieved the broad environmental goals desired by the public and mandated by Congress and State legislatures.

2.1.2 A New Environmental Policy - It is time for EPA to establish a new national environmental policy based on a hierarchy of strategies for risk reduction for all environmental media. The policy would establish preventing waste, residue and contaminant generation as the primary method of risk reduction. Preventing the generation of wastes, residues and contaminants through source reduction or by natural resource management would yield the greatest risk reduction because it eliminates or reduces exposure to public health and the environment. As evidenced by the large cost of remediating problems from inappropriate hazardous waste management, prevention is often the most cost effective risk reduction strategy. After exhausting these methods, strategies to recycle or reuse wastes and prevent or reduce the release of contaminants would be applied. Next, treatment, destruction, accident prevention and other control techniques would be utilized to minimize the quantity and toxicity of substances released into the environment. Recognizing that such a policy cannot be fully implemented for all environmental problems in the short run, it will also be necessary to look at other exposure reduction techniques. Strategies such as containment, pollutant dispersion or protecting individuals from exposure would be employed as a last resort in controlling or avoiding any residual exposure from potential polluting activities. Figure 5 on page 10 describes the conceptual idea of this environmental policy. Table 1 on page 6 describes a number of actions individuals, groups, industry and other institutions can take to reduce risks in the framework of this new environmental policy paradigm.

2.1.3 A Strategy for Risk Reduction Research - Such a national policy would provide EPA's Office of Research and Development (ORD) with a consistent conceptual framework for developing its risk reduction research strategy. This research and development strategy should focus on scientific and technical areas having the greatest potential for reducing risk to human health and the environment. This strategy will allow EPA to control pollution efficiently by focusing the limited resources of EPA on situations where wastes, residues and contaminants have the greatest impact and where, therefore, the greatest reduction of risk can be accomplished.

Such a research strategy should be based on a systematic way to evaluate the risks to health and the environment and must consider:

a. assessment of sources, transport to a receptor and transformation during the transport and ultimate fate of the contaminants,

b. evaluation of the exposure that humans or the environment receive,

c. determination of the effects that result from that exposure,

d. measures to reduce the risks that result, and

e. characterization of risk to humans and the environment.

This system is depicted in Figure 1 on page 2. Risk reduction measures can occur at many locations in the cycle and are a key component in EPA decision-making and in the mission of EPA.

EPA's research and development strategy should identify and quantify the links in the risk assessment-risk reduction scenarios for specific major problem areas. Problem areas within EPA and state responsibilities and mandates should be considered as well as emerging problems such as global climate change.

The identification and quantification would:

a. more clearly identify scientific uncertainty,

b. indicate where more knowledge would reduce that uncertainty and reduce risks to human health and the environment,

c. provide a better logic base to allocate limited resources, and

d. provide better information on which to base regulations.

The risk reduction part of the research strategy would focus on determining what research and development activities are needed to reduce risk to human health and the environment and what is the proper timing of that research and development. Most importantly, the clearer, firmer logic for EPA research and development activities should make it easier both to prioritize competing research needs and to balance them based on the extent to which the research will reduce risks to human health and the environment.

2.2 Defining Core Areas Within The Elements Of Strategic Risk Reduction Research

Selection of core areas for long range risk reduction research should be guided by the following three criteria. The core areas should address problems that are expected to persist over a period of a decade or more; problems where generic research will support a number of existing and anticipated EPA programs; and problems which are unlikely to be addressed by the private sector.

Workshops involving the appropriate experts, from both ORD and academia, with representatives from the program offices and industry would establish both the core areas and the comprehensive research program directions within each area. In this manner, programs of high scientific quality relevant to EPA's goals can be formulated. EPA would also convene periodic workshops to review the relevance of the core areas and to update their programs.

EPA should maintain strong scientific programs in the core areas. "Having a research program of high quality could pay off for EPA also by enabling it to work with other agencies as a leader, not as a 'lead agency' in the way OMB uses that term, but as a scientific leader."(13) EPA should encourage researchers in the EPA laboratories to become world-class investigators in their areas by publishing in premier journals and by presenting papers at international society meetings. The active involvement of EPA researchers at the frontier of their fields would enhance the EPA's credibility, and provide to EPA early access to research being done in other laboratories.

Examples of core areas, to be identified and refined by the workshop process defined above, follow. The EPA OEETD report on strategic risk reduction research and development (5) identified research needs which are listed in Appendix C, categorized by the core area into which they might fit.

2.2.1 Defining the Universe of Risk Reduction Techniques - Traditional environmental protection programs have employed a variety of technology-based strategies for risk reduction. Most such strategies employ devices to collect, store, convert, destroy or block the movement of contaminants to meet environmental standards and/or to cut down on unsafe exposures. For a variety of reasons, risk reduction techniques and strategies which reduce or prevent the production or release of contaminants to the environment without employing treatment or control technology are being increasingly utilized. However, research on these techniques has been meager and has suffered from having an inadequate conceptual framework to evaluate efficacy, potential implementation problems or long term costs. Because of the increasing interest in these techniques and their potential to have both positive and negative impacts on a broad range of societal values it is imperative that EPA have a strong, coordinated research program on these techniques.

Many of these risk reduction strategies, such as, prohibition of hazardous substance production, product substitution or aquifer protection zoning are often considered to be policy oriented or "soft science" and have been developed and evaluated by EPA program and policy offices. The

EPA Office of Research and Development (ORD) has concentrated largely on technology-based risk reduction strategies. However, non-technology-based techniques are extremely important and deserve the same systematic, rigorous development and evaluaton as is traditionally applied to scientific and technology-based strategies. Accordingly, EPA should consider expanding the role of ORD to include research on these strategies. While this would cause some minor organization disruptions it could greatly enhance the credibility and use of those strategies.

2.2.2 Preventing Waste and Contaminant Generation

The most effective strategy to reduce health and environmental risks is to prevent the generation of environmental contaminants. This strategy has two components:

a. source reduction, defined as changing industrial production input materials and processes, substitution of products using different raw materials, changing energy production methods and fuels, and resource conservation which eliminates or reduces the release of contaminants into all environmental media - air, water and land, and

b. management of potentially polluting activities through strategies such as local or regional land-use zoning to protect critical resources, land purchase and acquisition, and watershed management to effectively limit the generation or release of contaminants in critical resource areas or population centers.

Source reduction should be applied to all potential environmental contamination sources, from pesticides and toxic substances to air and water pollution and hazardous and solid wastes.

The research strategy should address both components of the waste and contaminant prevention strategy. The current waste minimization strategy should be expanded to cover all environmental media programs, including pesticides and toxic substances. In this context, waste should be defined as any non-product substance (solid, liquid or gas) that leaves a production process or site or that is released into the environment in handling, use or storage. The research program should be oriented toward:

a. understanding and developing strategies to overcome barriers to and create incentives for source reduction. Priorities include development of improved methodologies for costing waste management alternatives, including life cycle costs, and potential legal liabilities,

b. improving technology transfer, technical assistance and education programs designed to promote source reduction,

c. quantitative measurement of source reduction and recycling accomplishments relative to production output and other benchmarks of progress,

d. improving production and use of materials which can result in environmental contamination,

e. improving, refining and developing better natural resource management strategies such as local and regional land-use zoning controls to protect critical resources, land purchase and acquisition, and watershed management,

f. integrated pest management to reduce pesticide and fertilizer use,

g. strategies involving substitution for and prohibition of the use of harmful substances, and

h. energy conservation strategies.

2.2.3 Recycling and Reuse - Environmentally sound methods of recycling and reuse of potential contaminants can eliminate or greatly reduce the release of contaminants to the environment, reduce the amount of waste to be treated or disposed of, and reduce the generation of pollution from the use of virgin materials. For example, the recycling of solvents in an industrial facility can eliminate air pollutant releases and hazardous waste which must be incinerated or landfilled.

The research strategy should include the following elements:

a. expansion the recycling component of the current waste minimization strategy to all environment media,

b. research on strategies to create adequate markets for recycled goods (secondary materials),

c. understanding and developing strategies to overcome barriers to and create incentives for recycling,

d. development of improved methodologies for costing waste management alternatives, including life cycle costs and potential legal liabilities, and

e. research on ways to recycle specific products and pollutants which create the most significant problems when released or disposed of, e.g., plastics, solvents, batteries, tires, inks, pigments, autos.

2.2.4 Treatment and Control -- Strategies to prevent the generation of contaminants and/or strategies for recycle should be the first choices for risk reduction. When these strategies have been exhausted, strategies and techniques which destroy, treat, detoxify and reduce either the volume or toxicity of environmental contaminants should be applied. This approach will reduce and, if applied vigorously, minimize the release of environmental contaminants.

There are a number of strategies for controlling environmental releases to reduce or minimize the potential for release of and exposure to harmful substances. These include:

a. facility management programs such as

- o accident and spill prevention systems
- o information, audit and control systems
- o plant risk analysis,

b. auto emissions inspection and maintenance programs,

c. environmental monitoring and surveillance systems, and

d. labelling of products to ensure safety of use, recycling and proper disposal.

EPA should develop a coordinated, systematic research program to evaluate and further develop such strategies as an important component of risk reduction research.

Further combustion and thermal destruction research can contribute to treatment and control of wastes, residuals and contaminants. The products of combustion of fossil fuels are pervasive in our industrial society. This source accounts for the emission of 90 tons/capita per year of combustion products in the U.S., is the dominant source of the criteria pollutants, and is the cause of current concerns with pollution on a local (NO and CO in homes), regional(NO_x and SO_x), and global(CO_2 and N_2O) scale. This source has the potential of being of continuing concern into the forthcoming decade and beyond into the 21st century as fuel consumption and combustor designs change. In addition, the high temperature processes in combustors for fossil fuels, in wood stoves, in municipal and hazardous waste incinerators, and in a number of the high temperature pyrolysis and other thermal destruction methods proposed for Superfund sites have much in common. Generic research areas could include the following:

a. The chemistry of high temperature reactions: Models of the reactions in flames and pyrolysis units, together with mixing models, will be of benefit for defining products of incomplete combustion (PICs) in incinerators or for anticipating the conditions that lead to the formation of previously unsuspected pollutants such as N_2O in furnaces.

b. Mixing: Much can be gained from a more fundamental understanding of the mixing process in order to reduce emissions from a wide range of combustors. For example, the effectiveness of destroying NO in furnaces by hydrocarbon injection(reburning) or the burnout of primary pyrolysis products in the secondary combustion chamber of hazardous waste incinerators or above the grates in a municipal incinerator depend upon attaining mixing of the reactants at a molecular level.

c. Aerosol generation and elimination: The vaporization of trace metals from the incineration of municipal sludges, municipal solid wastes, and hazardous wastes as well as from the inorganic constituents of coals and oils results in the formation of fine aerosols that are difficult to collect. Understanding of the mechanism and the rates governing the processes could both better guide the field monitoring programs designed to evaluate this mode of mobilization of heavy metals, as well as suggest improved combustor operation to minimize emissions.

d. Gas-solid reactions: Problems that will certainly continue to be of concern over a decade include the capture of sulfur by limestone, the burnout of a solid residue in an incinerator, the development of advanced sorbents for gasifiers with the potential for high temperature applications. These problems are part of a wide class of gas-solid reactions, the understanding of which could lead to improvements in processes such as acid gas removal or the reduction of the formation of a throwaway by-product.

e. Development of real-time monitors: Monitors for continuously measuring the emissions from incinerators would, by providing a means of rapidly responding to process upsets, enable the reduction of emissions of products of incomplete combustion and, hence overcome some of the objections to the use of this technology. A number of options exist, but require the development of toxicological and risk correlations between the compounds of concern and compounds that are readily measureable.

This partial listing illustrates the potential for defining areas of research in combustion that pertain to several classes of problems which fall in EPA's purview. Combustion is an area of research pertinent to other agencies. EPA's role should be the development of a long range research program built around topics, such as mixing and kinetics, that can serve short-term goals on identification and destruction of PICs or acid rain precursors, as well provide information that would be relevant to potential future problems.

Physical and chemical treatment can be used to destroy, treat, detoxify and reduce either volume or toxicity. Among the more pervasive environmental problems is the treatment of waste streams containing very low concentrations of pollutants. The pollutants may be dispersed in a gaseous, liquid, or solid stream either in a molecular form or as fine particles(aerosols or colloids). The challenge is to achieve high removal efficiencies at low concentration levels, while minimizing the formation of undesirable by-products, and to develop cost-effective technologies in process. These problems have been of importance throughout the history of the EPA. Many of the problems are site-specific and are being adressed by the private sector. There are, however, a large number of medium and small companies utilizing chemicals that do not have the technical resources to recognize the environmental problems to which their effluent streams may be contributing or to develop and implement an appropriate control strategy. The EPA has an important contribution to make in conducting the risk reduction research for these smaller and medium sized companies.

Additionally, EPA needs to conduct risk reduction research for problems generated by households, by municipalities, and by other parts of the public sector. Air toxics illustrate these problems since a major fraction of the organic molecules in urban atmospheres comes from a wide variety of dispersed and currently unidentified sources. Another example is the contamination of both drinking water and effluents from municipal wastewater treatment systems, where traditional treatment methods are often found to be inadequate.

Suggestions for the type of core research that could be done include:

a. Fine Particle Controls: The control of the emissions of toxic metals requires the development of improved understanding of the control of the fine particles produced by vaporization/condensation. Particles in the 0.1 to 1.0 micron size range are of special concern.

b. Absorption/Desorption: Better understanding of the absorption and desorption by high surface area porous solids would be of benefit for both the better design of filters, such as activated carbon, and for the possible development of more economical means of removing trace contaminants from soils.

c. Concentration of Wastes: Economies can be achieved by reducing the volume of the waste stream. Innovative methods such as supercritical extraction, liquid membranes, and reverse micelles are providing new directions in separation technology.

d. Advanced Chemical Treatment: Detoxification of wastes by chemical treatment is very cost-effective. The method must be tailored to the waste in question since the chemical reactions are specific to a compound or class of compounds, and the method of application depends upon the physical nature of the waste. The on-site dechlorination of compounds in soils(the APEG and KPEG processes) is a good example of the potential of such technologies.

By far the most versatile, cost-effective approach for treating most organic pollutants at low concentration is through <u>use of biological systems for controlling pollutant release</u>. A continuing core research program is needed to take full advantage of such systems. A research initiative EPA proposed in this area in March 1987 (17) should be supported; however, more emphasis should be placed on utilizing naturally occuring organisms than was originally proposed.

Key generic research activities in this area of include the following:

a. Identify and characterize biotransformation processes occurring naturally in surface waters, soils, and aquifers. Establish optimal conditions to enhance transformation rates.

b. Evaluate the utility of genetically engineered organisms in effecting transformations not achievable by natural organisms at reasonable rates.

c. Develop new biosystem concepts for incorporating natural and engineered organisms and conditions to effect desired transformations. Include in situ treatment as well as centralized treatment facilities. Develop improved mathematical models to describe biological treatment operations. Initial emphasis may be on cleanup of Superfund sites, but the program should have broad pertinence to wastewater treatment, land treatment, and aquifer restoration. Include research on anaerobic and aerobic systems for wastewater treatment and sludge stabilization, on enzymatic reagents and delivery systems for treatment of contaminated soils, and on treatment of combined sewer overflows.

d. Determine the environmental fate and effects of the treatment residuals, including engineered organisms. Develop means for proper communication of risk (or lack thereof) to the public.

e. Develop means to mitigate adverse consequences of the release of engineered organisms.

f. If not covered under other programs, include research on pathogen inactivation.

2.2.5 Reducing Exposure After Optimum Pollution Prevention, Treatment and Control -- Once the generation of environmental contaminants has been reduced and the release of the remaining contaminants has been controlled to the optimum extent, any remaining risk must be addressed by avoiding or minimizing exposure. This can be accomplished by strategies such as proper land containment, pollutant dispersion, use of home water treatment devices, buffer zones and risk communication.

An important part of the EPA risk reduction research strategy must be a viable, strong research program that investigates sound approaches for the land containment and disposal of wastes and residues. Land disposal will continue to be a very important risk reduction activity. There are only three major ultimate disposal locations: air, water and land. Although other options exist and will be used, land disposal has a continuing, inevitable and important risk reduction role for EPA and for the nation. Land disposal options will continue to be needed, and as part of meeting overall EPA needs, land disposal research can help assure that such disposal will be protective of human health and the environment.

Environmentally sound land disposal practices will be needed even more in the future for: municipal solid waste, household hazardous wastes, very small quantity generator hazardous wastes, residues resulting from treatment of hazardous wastes; high volume wastes such as fly ash, bottom ash and mining wastes; CERCLA remediation and removal wastes; incinerator residues; demolition wastes; and contained wastes that have no other technically feasible or economic disposal alternative. In addition, technology is needed to retrofit existing land disposal facilities and for future facilities. EPA needs a strong land disposal research program (LDRP) to address these issues.

Another need that can be met by a strong LDRP is to evaluate and understand the long-term performance of what are now considered environmentally sound and technically appropriate land disposal practices and the associated monitoring methods to assure that they are environmentally sound over many decades. In spite of the research conducted to date, it remains very difficult to predict that improved land disposal practices, such as "secure" landfills, will protect human health and the environment in future decades. Without such an understanding, the nation will never have permanent verified solutions to the proper management of the above wastes and may find itself caught with the need of continuing to clean up waste disposal sites, because of no cohesive, viable LDRP.

A recent review (6) of the current EPA LDRP concluded that EPA does not have a waste management strategy that clearly defines the continuing role of land disposal and that recognizes the need for a strong and vital LDRP. Unless this is corrected, EPA and the nation will lack the scientific and technical knowledge necessary to the ongoing development of scientifically sound land disposal guidance and regulations.

This situation appears to have occurred because, as with almost all EPA programs, the LDRP is driven by immediate and legitimate program office needs for information to support Congressional mandates and court deadlines to develop regulations. As a result of changing program office direction, the research focus has shifted during the past decade. In the 1970's, the LDRP emphasized municipal solid wastes in response to the needs of the Solid Waste Disposal Act. With the passage of the Resource Conservation and Recovery Act (RCRA) in 1976, the focus began to change to the control of hazardous wastes. In recent years, the LDRP has evaluated whether hazardous waste land disposal methods are protective of human health and the environment. With the current (RCRA) emphasis on alternative technologies to land disposal (needs that resulted from the requirements in the 1984 RCRA Amendments), the perceived need for hazardous waste land disposal research efforts has declined. These funding reductions cripple the program's ability to meet future technical requirements in regard to the use of environmentally sound land disposal methods. The net effect of these cumulative individual decisions results in EPA being left with a LDRP that does not meet the Agency's overall long-term needs.

The Science Advisory Board review (6) recommended numerous efforts that should be part of a land disposal research strategy. These included:

a. identification of changes in the characteristics of wastes likely to be land disposed in the future,

b. field scale research to have a technical understanding of the performance of cover and liner systems. The emphasis on land disposal closure and post-closure operations and monitoring should be increased because many land disposal facilities recently have closed, and others will close,

c. research on approaches and designs that facilitate liner and cover repairs,

d. evaluation of monitoring data at permitted facilities to evaluate containment designs, and

e. an increase in cooperative efforts with the private sector to develop better analytical and evaluation methods for constructing and defining the performance of land disposal components and systems.

Assuming that opportunities to mediate those environmental processes which transport and transform the contaminants are uncommon and also that personal protective devices are an undesirable last resort, then a promising area of research concerns education of the public on personal exposure avoidance.

Research into human exposure avoidance embodies sociological, cultural and psychological issues. Learning what motivates people to take action concerning their health and how to prepare and deliver educational materials to be effective are essential elements. Exposure avoidance, by personal action, deserves its place along with source reduction and control as an important element in a strategy of risk reduction. A companion research program in total human exposure would provide the technical information used in the exposure avoidance.

Other programs in risk reduction through exposure avoidance relate to protection of pesticide applicators and asbestos abatement workers; drinking water treatment (central and at point of use); providing alternative sources of drinking water, indoor air ventilation, and land use planning (e.g. industrial buffer zones). Of these, continued core research programs are recommended on drinking water treatment (particularly at point of use) and on the reduction of indoor air pollution from passive smoking, asbestos, solvents, combustion products and radon.

Proper siting of noxious facilities is an important strategy in reducing public exposure and environmental contamination from harmful substances. EPA's research strategy should address both technical and non-technical strategies to improve government decision-making on siting potentially noxious and polluting facilities. The research should focus on improving the use of siting as a strategy to minimize public exposure and environmental contamination and on overcoming barriers to siting, recycling, treatment and disposal facilities needed to reduce environmental risks.

2.2.6 Selecting Risk Reduction Strategies -- The selection of risk reduction strategies to achieve desired risk reduction goals will involve a variety of legal, scientific, economic, political and social factors. However, one critical element in making these decisions is the communication between decision-makers, parties affected by the decisions and others, e.g., the news media and academics, who report, chronicle and evaluate these decisions. Indeed, some would argue that risk communication is the most critical element in such decisions. Because it is newly emerging as a defined subject area of intellectual organization and because of its importance, EPA should expand and develop a strong research program in risk communication.

The importance of risk communication to risk reduction efforts was recently expressed by Milton Russell, former assistant administrator for Policy, Planning and Evaluation at EPA. Russell observed that:

> "Real people are suffering and dying because they don't know when to worry, and when to calm down. They don't know when to demand action to reduce risk and when to relax, because health risks are trivial or simply not there. I see a nation on worry overload. One reaction is free floating anxiety. Another is defensive indifference. If everything causes cancer, why stop smoking, wear seat belts or do something about radon in the home? Anxiety and stress are public health hazards in themselves. When the worry is focused on phantom or insignificant risks it diverts personal attention from risks that can be reduced."

Implicit in Russell's statement are two basic functions served by risk communication. One is the provision of basic information and education in order to help people understand risk and put it in perspective so that they will know "when to worry and when to calm down." Communications about the risks from eating flour contaminated with EDB or drinking water containing radioactive fallout from Chernobyl are examples of this category of information. The second function is to communicate in order to motivate necessary risk-reducing actions such as renovating a home that has high radon levels or disposing of household chemicals properly.

The goal of informing people about risk and motivating behavior change sounds easy in principle but is surprisingly difficult to accomplish. To be effective, risk communicators must recognize and overcome a number of obstacles. First, doing an effective job of communicating means finding comprehensible ways of presenting complex technical material that is cloaked in uncertainty and is inherently difficult to understand. To further complicate matters, risk information may make a hazard seem more frightening, even when the aim of the message is to calm public concerns. When public attitudes and perceptions are well established, as with nuclear power, they are hard to modify because new information is filtered in a way that protects established beliefs. However, when people lack strong prior views, the opposite situation exists--they are at the mercy of the way that information is presented or "framed." In such cases, subtle changes in the ways that risks are expressed can have a major impact on perceptions and decisions.

Understanding <u>risk perception</u> is critical to clearly "framing" and communicating risks to the public. Many risk analysts have argued that health risks can best be understood and appreciated by means of comparisons with risks from other (often more familiar) activities. Such comparisons are thought to provide a "conceptual ruler" that is intuitively more meaningful than absolute numbers or numerical probabilities. Yet, to date, there is little specific knowledge about how to formulate such comparisons and determine whether or not they communicate effectively. There is a need for creative new indices and analogies to help individuals translate risk estimates varying over many orders of magnitude into simple, intuitively meaningful terms. The task will not be easy. Ideas that appear, at first glance, to be useful, often turn out, upon testing, to make the problem worse. For example, an attempt to convey the smallness of one part of toxic substances per billion by drawing an analogy to a crouton in a five-ton salad seems likely to enhance one's misperception of the contamination by making it more easily imaginable. The proposal to express very low probabilities in terms of the conjunction of two or more unlikely events (e.g., simultaneously being hit by lightning and struck by a meteorite) also seems unwise in light of experimental data showing that people greatly overestimate the likelihood of conjunctive events. Perhaps public understanding of quantitative risk can be improved by studying their understanding of commonly used measures, such as distance, time and speed.

The sensitivity of risk communications to framing effects points to another avenue for research. We need a better understanding of the magnitude and generality of these effects. Are public perceptions really as malleable as early results suggest? If so, how should the communicator cope with this problem? One suggestion is to present information in multiple formats--but does this help or confuse the recipient? Finally, the possibility that there is no neutral way to present information, coupled with the possibility that public preferences are very easily manipulated, has important ethical and political implications that need to be examined.

Because of the complexity of risk communications and the subtlety of human response to them, it is extremely difficult, a priori, to know whether a particular message will adequately inform its recipients. Testing of the message provides needed insight into its impacts. In light of the known difficulties of communicating risk information, it could be argued that an agency which puts forth a message without testing its comprehensibility and effectiveness is guilty of negligence or at least of short sightedness. This assertion raises a host of research questions. How does one test a message? How does the communicator judge when a message is good enough in light of the possibility that not all test subjects will interpret it correctly?

Risk communication is closely linked with risk perception. To communicate effectively, we need to understand the nature of public knowledge and perceptions. Thus, a comprehensive research program on risk reduction also needs to include research on risk communication and perception.

Some general research questions dealing with research on risk communication and perception are:

a. What are the determinants of "perceived risks?" What are the concepts by which people characterize risks? How are those concepts related to their attitudes and behavior toward environmental hazards?

b. What steps are needed to foster enlightened behavior with regard to risk? What sorts of information do policy makers and the public need? How should such information be presented? What indices or criteria are useful for putting diverse risks in perspective and motivating desirable behavior change? How should uncertainty be explained to the public and to policy makers?

c. What makes a risk analysis "acceptable?" Some analyses are accepted as valuable inputs to risk management decisions, whereas others only fuel controversy. Are these differences due to the specific hazards involved, the political philosophy underlying the analytical methods, the way that the public is involved in the decision-making process, the results of the analysis, or the incorporation of social values into risk analysis?

d. How can polarized social conflict involving risk be reduced? How can an atmosphere of trust and mutual respect be created among opposing parties? How can we design an environment in which effective, multi-way communication, constructive debate, and compromise can take place?

e. Are certain contexts of risk communication more or less conducive to the processing of risk information? The information-theoretic model of risk communication has been useful to a limited degree, but it is too constraining. In addition to looking at information flow, channels and receivers, we have to look at the social and cultural contexts within which scientific information gets transmitted.

f. In dealing with public perceptions of risk, we need research that examines how people come to an understanding of risk in real time, under actual conditions. Ethnographic case models are important. Laboratory models of risk perception have provided an important conceptual framework, but they need to be complemented by analytic case studies.

g. How do we get consensus in the expert community? What are the factors that impede consensus? We need to know more about the problem of risk communication between experts.

h. How should lack of scientific consensus be transmitted to the lay public? We need to clairfy and describe the issues in an understandable manner for public consumption.

Risks can be defined as threats to people and things they value (their health, their finances, the quality of their environment). Considerable research has been directed toward assessing values associated with human mortality and morbidity, so that these values could be factored in to risk benefit analyses. Much less attention has been given to the valuation of environmental features such as clean air and water, protection of plant and animal species, etc. Typically these valuation efforts have been approached from an economic (e.g., cost-benefit or willness to pay) perspective. For instance, the public and policy makers are asked to assume that a market exists for trading such "goods" and they are asked to estimate appropriate "prices" expressed in terms of "willingness to pay" to save (or to avoid the loss of) a human life, to clean up a polluted lake, to preserve an animal species, and so on.

The market approach to valuing goods for which no market actually exists has come under severe criticism, however, on the grounds that it is biased at best and invalid at worst. It appears that many outcomes associated with environmental protection may simply not be able to be evaluated in terms of well-defined dollar values that can be compared with monetary values for traded goods or services. People may care about maintaining a clean environment, reducing perceived risks, protecting their health, or preserving a threatened animal species without really being able to express the importance of such outcomes in terms of monetary values. Instead, their values may reflect a complex mix of aesthetic, moral, political, psychological, social and economic concerns that need to be measured by innovative new methods. The methodology of multi-attribute utility theory, for example, might be used to construct overall values from the component dimensions of value.

Thus, despite modest research efforts in the past, we still lack the ability to evaluate many outcomes associated with environmental protection. We need a fresh approach, one that starts by looking beyond economic components of value, which are important but are only part of the story. Research is needed to determine what the components of "value" really include and how they can be measured in a manner that is reliable enough and valid enough for input into policy decisions. Such research will need to proceed from an interdisciplinary base in which the efforts of psychologists, ethicists, economists and others are closely coordinated.

2.2.7 Incentives for Risk Reduction -- Risk reduction strategies will only be effective if properly implemented. Although taken for granted, seldom is the implementation strategy considered in evaluating and chosing a risk reduction strategy. Most risk reduction strategies are mandated by legislative, executive and judicial branches of government. However, it should be realized that risk reduction strategies are aimed at influencing the behavior of individuals, groups and institutions to reduce environmental risks. Creating incentives to change behavior is what most environmental law and regulation aims to do. There are strategies other than government command and control and market-place factors to create the proper incentives for risk reduction. EPA should develop a coordinated systematic research program on such alternative strategies. The research program should include factors motivating behavior. Priorities should be given to:

a. Economic incentives through fees, taxes, grants, loans, etc.,

b. Evaluating the incentives and disincentives to applying risk reduction strategies, and

c. Understanding motivations of individuals, groups and institutions to foster changes in behavior which will result in risk reduction.

2.3 Education and Technology Transfer

One of the greatest difficulties in implementing innovative risk reduction strategies is getting the information in the hands of institutions and people who can implement the strategies. For example, they are often faced with a proposal for a new facility which wishes to employ a new technology for risk reduction. In addition to checking the literature and consulting professional colleagues, state and local officials often call EPA and sometimes other states for advice. They do so for several reasons. They assume EPA has or should have the expertise to evaluate the technology, and that EPA and other states may have been faced with similar issues. Moreover, state and local governments feel that they are on firmer ground with the backup of EPA or another state which condones, has approved or utilized the technology or strategy. State and local governments also perceive the value of technology transfer activities to their communities and local economies. EPA assistance that enables communities to achieve environmental goals more cost-effectively is clearly beneficial. The current mechanism for obtaining this assistance is an ad hoc system of individual contacts with occasional seminars, training courses and conference by EPA.

The problem is not unique to state and local government. Business and industry (particularly small and medium sized) also need a better mechanism for obtaining information about risk reduction technologies and strategies. For reasons of competition and lack of expertise or other resources, small and medium sized industries do not often have access to the latest information to reduce risks. An important example of this is getting information to (and acceptance by) farmers on integrated pest management to reduce risks from pesticide exposure. Similarly, the public which is demanding and having a larger role in government and private decision-making on environmental protection needs information on the effectiveness and application of risk reduction strategies and technology.

Moreover, academic programs at universities and other institutions must have access to information on innovative risk reduction strategies to ensure that educational programs will be providing the personnel who can implement risk reduction programs.

To date, EPA has not had a coordinated, comprehensive strategy for communication and education on risk reduction strategies. This is especially true for the Office of Research and Development which has been unable to budget resources for technical assistance, technology transfer and communication, except in a few specialized cases.

EPA should develop a comprehensive, regular program for communication, education and technology transfer across all environmental media. The report of the Administrator's Task Force on Technology Transfer and Training is an important step forward for EPA; its recommendations should be fully implemented.

2.3.1 <u>Education and Training Programs</u> -- It is important for EPA, private industry, trade and professional associations, and universities to work cooperatively to incorporate training in environmental issues into the curricula of a number of disciplines relevant to environmental management. It is critical that much more integrated views of product design, production processes, waste generation, product handling and use, non-engineering approaches, cost effectiveness, and pollution control that relate to all risk reduction strategies be developed in such fields as civil, environmental, chemical process, mechanical, electrical and petroleum engineering; business; public policy; economics; medicine; public health and law. As an example, pollution control -- much less environmental protection --- cannot continue to be thought of only as an "end-of-pipe" treatment of wastes. A sound integrated curricula would not require separate courses on topics such as source reduction and waste audits. Rather, the curricula would teach the implications for pollution generation of actions not traditionally associated with pollution. An example is to incorporate waste elimination as a goal of a design problem on manufacturing computer chips.

EPA should work actively with groups such as the National Research Council, the National Science Foundation, the American Institute for Chemical Engineers, the Association of Environmental Engineering Professors, the Accreditation Board for Engineering and Technology, the American Academy of Environmental Engineers, the American Medical Association, the American Public Health Association and the American Bar Association to advocate such changes.

In addition, EPA should support the development and implementation of such education programs. Such programs could include education and training materials, handbooks and other written and audiovisual materials and also seminars and training courses. The success of the existing regional asbestos training and information centers sponsored by EPA are an excellent example of the value of such programs that should be replicated for other risk reduction strategies.

Priorities for consideration should include

a. lead paint removal,

b. radon mitigation,

c. integrated pest management,

d. chemical accident risks,

e. hazardous waste management,

f. support of curriculum development at universities in environmental management and risk reduction, and

g. support of graduate fellowships, traineeships and research assistantships -- EPA has an excellent program of environmental policy research performed by graduate students at 25 universities through its National Network for Environmental Policy Studies. The current program should be expanded and to include risk reduction strategies.

2.3.2 Technology Transfer -- As stated in introduction to the "Report on the Administrator's Task Force on Technology Transfer and Training," (14) technology transfer is an essential element of the EPA mission:

"The evolution of environmental programs has changed the climate and conditions under which EPA operates, challenging the Agency to adapt to these new conditions and expand its role to meet new needs. As the environmental programs of the 1980s develop and mature, more of the work in environmental protection is being carried out in the field by the EPA Regional Offices and State and local government agencies. In addition, the Clean Air Act, Resources Conservation and Recovery Act (RCRA), Superfund (CERCLA), Safe Drinking Water Act, and Clean Water Act all mandate more involvement by State and local governments in implementing the statutes. This evolution has a significant impact on EPA's approach to carrying out its mission, prompting it to extend its role beyond its traditional focus on enforcement and regulation to a renewed emphasis on technology transfer and training as means of accomplishing environmental protection goals. As EPA moves into this new and expanded role, the Agency has a unique opportunity to redefine and forge new relationships with States, local governments, industry, and academia that are based on partnership and cooperation."

. . .

"Compliance with environmental regulations can be more readily accomplished if monitoring and enforcement activities are combined with a program of technical assistance and training. Further, many areas of environmental concern, such as the radon and nonpoint source water pollution problems, do not lend themselves to the traditional regulatory and enforcement approach; in these cases, technology transfer and training can provide a mechanism for the development of positive solutions that draw on the unique strengths of all parties involved. EPA, working in partnership with the States, must take action to legitimize the importance and integral nature of technology transfer and training to its mission. As the Agency continues to evolve and mature, technology transfer and training must become core elements in supporting the Agency's operations and interactions with the states and local government, industry, and academia."

. . .

"Further, the Task Force believes that failure to incorporate such an emphasis throughout the Agency will undermine the effectiveness of the Agency's regulatory and enforcement efforts, and related activities at the State and local level."

The Task Force is not alone in its view that technology transfer and training will be crucial components of EPA's future role. Congress emphasized the importance of technology transfer by unanimously passing the Technology Transfer Act of 1986. This incentive-oriented law was further buttressed by Executive Order 12591, which encourages cooperative consortia among government, academia, and industry for the development and commercialization of new technology.

The Administrator's Task Force report is correct. A strong technology transfer program is essential to achieving risk reduction goals and should be a component of the ORD program or risk reduction research. Such a program should:

a. have an Office of Technology Transfer in the Office of Research and Development -- This office would coordinate activities with similar entities in the Office of Regional Operations and other program offices,

b. establish technology transfer and training as legitimate core elements of the Agency's approach to accomplishing its mission and include them as part of the program budget,

c. develop cooperative partnerships among government, industry, and academia for technology transfer, and

d. explore innovative programs such as the use of retired professionals, exchange of personnel among EPA headquarters, laboratories, regional offices and states through the Intergovernmental Personnnel Act or use of unemployed persons for risk reduction work -- These programs should be implemented with the assistance of states and unversities to foster the most effective outreach.

EPA should expand its current technology transfer program on waste reduction to other risk reduction areas as an example of an increased effort in technology transfer. The current program to develop and test assessment procedures suitable for identifying potential waste reduction opportunities for major hazardous waste generating sectors, Waste Reduction

Audit Protocols (WRAP), is a good start but should be expanded to air and water discharge sources. Similarly, the waste reduction evaluations at federal sites, Waste Reduction Evaluations at Federal Sites (WREAFS), is an excellent idea but should be expanded to cover all environmental media at government facilities, not just at DOE and DOD. A handbook on source reduction and recycling such as that recommended by the July 1987 Waste Minimization Policy forum conducted by Tufts University for EPA is a mechanism of technology transfer which should be further developed. EPA should also consider development of expert systems in source reduction and recycling for use by states and industry.

In targeting technology transfer efforts, EPA should concentrate on groups and institutions where the greatest risk reduction results are likely to occur. In waste reduction, for example, efforts should be targeted initially to industries that use chemicals, but have little expertise in the chemistry of waste management. Such industries include the electronics, aerospace, and metal fabrication industries. In addition, EPA may want to consider the feasibility of implementing waste minimization practices in selected companies or industries. By beginning in industries that are most receptive, and on processes likely to generate positive results, it can establish a solid foundation for its program. Moreover, small and medium sized hazardous waste generators (plants that generate 1,000 - 100,000 kilograms of hazardous waste per month) could benefit most from source reduction technology-transfer efforts because they often are not aware of source reduction and recycling options and because implementing promising options could have a significant impact on waste generation nationally. Among medium-sized waste generators, the emphasis of technology-transfer efforts should be on users of chemicals, as opposed to chemical manufacturers, because users may lack the chemical engineering expertise to develop waste minimization approaches. A specific suggestion for source reduction opportunities that should be encouraged by EPA, other than those suggested in the ORD Strategy, is the design of new products that will minimize waste generation by customers or users of these products, such as solvent or pesticide users.

In summary, technology transfer is an essential element of EPA's risk reduction program. Technology transfer and training activities should not be separated from the broader mission of the Agency. Technology transfer and training are integral to the way EPA will do business in the future. Technology transfer and training activities are also investments in the future, whose true value may not become full realized in the short term.

2.4 Implementation Strategies for Risk Reduction Research

2.4.1 An Orientation to Solving Problems -- In order to be successful in bringing about environmental change, EPA needs to take a problem solving approach in dealing with State and local governments and private industry.

Rather than focusing only on the establishment of appropriate State and local laws and regulations, EPA needs to recognize the need to enhance operational capabilities of environmental agencies as well. Rather than looking at permit and enforcement actions as ends in themselves, the EPA needs to step back and decide the types of risk reduction techniques that it wants to bring about in specific instances. This should include waste reduction approaches as well as the more traditional control technology approaches. The EPA should then consider all of the tools at its disposal in order to make the desired changes. In some cases enforcement action may be appropriate. In other cases a technology transfer program which could include joint EPA-industry development and testing might be a better approach. Technical assistance and training to State and local agencies, who then in turn could work with particular industries, should also be considered. Public education may be necessary in order to obtain approval for desired results (e.g. the siting of a new treatment technology). The important point is that the Agency must assume a more proactive leadership position in bringing about environmental change and that it should constructively support State and local government and industry through training, technical assistance and technology transfer as well as conducting risk reduction research.

2.4.2 Establishing and Updating Priorities for Risk Reduction

Risk assessment is one tool for identifying and quantifying risks. Most current EPA risk assessment activity consists of two major parts. The first part is exposure analysis. This is figuring out how many people have been exposed to what chemical, for how long, and at what levels. The second part is producing dose-response curves directly from health data or, indirectly, by analogy with known effects of similar chemicals. The results of these two parts combine to compute what part of the population may have a health effect at each level of severity as a result of exposure. (See Figure 2, page 2). Although this currently represents the main tool, it is severely limited by the paucity of relevant exposure data, and is clearly not adequate for ecosystem degradation modeling. We leave that discussion to others.

Each of the two technical parts mentioned above is only as accurate as the means and dispersions of the exposure distributions and dose-response curves, and the accuracy of techniques for projecting health effects from one chemical to another. The technology and databases for all three are constantly changing.

EPA should have a core research program to increase the reliability of these methods. Often load limits for toxic chemicals are determined using a "margin of safety" to make up for the lack of accuracy of the curves. Developing more accurate curves by long-term basic research may mean more accurate load limits, as well as more focused and efficient prevention and remediation. This is a legitimate risk reduction research area.

After technical risk assessment, safety analysis then determines whether the levels of risk incurred are acceptable or whether plans should be made to reduce these levels in some way to an acceptable level. Considerations of societal norms, laws, regulations, and politics enter here. The mere publication of a safety analysis showing that practices are not acceptable and entail perceived risks may itself be a control technology. Such actions may result in reducing the risk due to public pressure on those responsible for the risk.

The technical part of an EPA risk reduction strategy consists of developing all feasible alternate control strategies for the sources, translocation, and transformation of chemicals which result in exposure, and evaluating these alternative control strategies for quantitative effectiveness by the technical risk assessment mentioned above. This includes investigation and evaluation of not as yet developed control technologies, used at control points in ways not previously investigated. These strategies cover a much wider range of possibilities than is often considered. Among these alternatives are waste minimization, multimedia source reduction, recycling, treatment, and disposal in all media.

This also includes education, as the population affected may avoid exposure by voluntary acts, such as moving or not buying products, or may apply political pressure to the manufacturer. These strategies will necessarily involve EPA, industry, internal and extramural research, technology transfer assistance programs, and educational programs.

Non-technological strategies may sometimes be more effective in reducing risk (and less costly) than very elaborate technologies applied to the production and transformation of the chemicals.

In summary, risk assessment has four stages:

a. identification of risks,

b. evaluation of severity of risks,

c. identification of strategies to control risks, and

d. evaluation of the effectiveness of strategies to reducing risks.

Each of these stages requires constant updating and necessitates an ongoing, core research program to update assessments.

Various criteria can be used to categorize risks.

a. Newly Emerging Risks: We may be presented at any time with suggestive or anecdotal evidence that exposure to a previously ignored chemical or biological substance may have serious consequent risks to man or the environment. Virtually all current EPA resources currently are budgeted to known problems. This should not result in putting off exploratory investigation of new presumptive risks. If, after exploratory analysis, the new risk is of so small a magnitude that remediation would yield an insignificant risk reduction relative to other known risks, the area of investigation may be dropped. But how should one get to that decision point?

b. Stratification of Populations and Areas by Risk Level: An error that should be avoided is dismissing the risks of exposure to a substance because the average exposure of a large population is small. Within the large population there may be identifiable high-risk groups and therefore extremely inequitable risks. A high risk for a few is not counter-balanced by a small average risk for the many. Such an approach is contrary to the assertion of many industrial risk assessors who make meaningless comparisons of the risks of exposure of employees to plant chemicals with everyday risks.

All risk assessments should be required to stratify exposed populations and areas by risk level, obtaining the distribution of risk. This often requires data gathering. For example, for house radon exposure, one method of gathering data is overflights which give a contour map of activity so that the physical areas where many individuals have high radon exposure can be pinpointed. In the non-pinpointed areas where the average exposure can be expected to be low, house-to-house radon variation is largely based on extremely local geology, and remediation is needed in many houses in these non-pinpointed areas. Getting the appropriate stratification to estimate who is at high risk and where they are requires care.

c. Recognizing the Vector Nature of Risk: A second error is thinking of the effect of a control strategy in an univalent way in terms of one effect. But getting the level of one chemical down often shifts exposure to other pathways. In the case of sludge, land spreading might cause heavy metals to enter the human food chain. Burning sludge causes those same metals to be emitted and possibly respired, and sea disposal may cause those same metals to enter fish and the human food chain another way. Multiple-media, multiple-chemical exposure effects of each proposed control strategy of remediation have to be established simultaneously in order to get a true picture of total health risks. Every control strategy proposed should be evaluated according to the vector nature of the resulting exposures.

This is currently not common practice, but ought to be attempted in evaluating control strategies.

d. Dose-Response Curves -- A Problem That Won't Go Away: A principal component of risk assessment is dose-response curves. These curves convert exposure into health effects, mortality and morbidity. How to extrapolate from short-term, high-dosage exposures in a laboratory on animals to results for long-term, low-dosage exposures of people in a natural environment is an area of great controversy and much theology and debate. Different models, based on different detailed assessments of biology and chemistry, give estimates orders of magnitude apart, and often are used to rank problems for suitability for mitigation or regulation. There is perhaps more dispersion of estimates in this part of risk assessment than in any other. This is an area where fundamental, theoretical and experimental research is required to evaluate these models according to EPA as well as state and local (e.g., community right-to-know) needs.

e. Screening Chemicals for Risks: There are a myriad of unexplored chemicals which may pose health hazards. Without availability of dose-response curves, based on animal experiments, and without waiting for complaints to pour in that new chemicals are risky, it would be much better to develop predictive tools, predicting health effects based on structure, using similarities to chemicals that have been tested in a dose-response arena. There is important EPA activity in this area, but its basic scientific justification as applied is limited. A research program should be jointly conducted with EPA, industrial, and university chemists and dose-response experts. Industrial chemists wish to avoid the use of, possible exposure to, and liabilities of high-risk chemicals, and have every reason to cooperate. Further, there is virtually no research on the synergistic or antagonistic effects of chemical soups, such as drinking water, with many different trace organometallic chemicals in many urban areas. It is perfectly possible that restricting each of these chemicals to a low level does not eliminate detectable joint health effects, for which new joint estimators are required.

f. Administrative Obstacles: Exploratory investigation to discover the likely extent of risk is often not possible within one office committed to one law or one medium. This points to the necessity of separate funding for exploratory analysis for identification of new risks. Such exploratory research is often interdisciplinary. One needs chemistry, physics, engineering, as well as biological and health sciences. One needs a cross-media, cross-exposure path and cross-chemical products approach.

g. One New Tool -- Exploratory Data Analysis: An important new discipline for looking for effects in data of uncertain origin when the effects are not known or understood in advance is Exploratory Data Analysis (EDA). This discipline is different from conventional statistics, which deals with analysis of data that has been collected according to statistical practice. It may be described as a collection of algorithms and concepts for rearranging massive data until one can see the effects and develop appropriate estimators. This discipline has converted the "art of" discovery of effects buried in data bases into "close to a science;" A science utilized before conventional statistics are used.

EDA is a very powerful new tool and should be taught to EPA scientific staff as a tool like FORTRAN or physics. EDA has many possible uses in EPA. A premier one is in the identification stage of risk assessment. It is especially effective whenever one has to consult large data bases that are not the result of designed experiments with controlled variables. EDA's effect-finding algorithms have been implemented for graphics work stations, so that the user needs only a surface knowledge of EDA and can use the human eye to detect effects by rearranging and transforming massive data bases in many different ways. EDA helps discover new and reliable estimators. EPA needs estimators of risk in all risk assessments. Such estimators are as diverse as BOD or linear health effect models; they represent the quantities, usually a compound result of measurements of a number of physical measurements, which represent a density or cumulative exposure, or an effect in dose-effect, for example.

We all know many cases when estimators have been used to establish toxic loads without adequate exploratory or confirmatory research to determine that these estimators are robust estimators of the intended risks. Systematizing the development of estimators is a task for exploratory data analysis; validating or confirming the choice is the domain of conventional science and ordinary confirmatory statistics. EDA is an exploratory rather than confirmatory tool. After the effects are discovered and good estimators are developed by EDA, systematic data collection and experiments can then be undertaken. Such an approach is likely to supply the grist for the mill of ordinary confirmatory statistics to more effectively validate the estimators.

h. Another New Tool: Expert Systems: Expert systems are extraordinarily versatile tools for technology transfer. The elementary knowledge and tools of the best workers in each area of risk assessment can record their knowledge in one of these "automated handbooks" for use by others in EPA, local, State and Federal Government, and industry. As long as one does not try to encapsulate knowledge that does not exist (where there are no experts), this is a viable tool for technology transfer, as long as the methodology, databases and models for risk are updated.

One might think that establishing risk-reduction research priorities would be merely a matter of applying the criteria to the identified risks. However, complicating factors include:

a. the relative importance of each identified risk and each criterion is viewed differently by experts having different perspectives,

b. essential support from EPA management and from those responsible for the budget is dependent upon people having perspectives often different from those of the experts, and

c. fruitful research requires a cadre of knowledgeable, dedicated people working in a given area over a period of at least a few years.

The answer seems to lie in establishing a few "continuing core research areas" and periodically convening persons representing a range of interests to ascertain if these still are the right core areas, what new research goals within these core areas are needed, and what funding is appropriate given the magnitude of the risk and chances of research contributing to reduction of that risk.

The core research areas would involve dedicated people at the ORD laboratories supported by cooperative agreements and by competitive grants to the scientific community. The latter is essential to get the best thinking into the program. The core research areas would have short-term regulatory deliverables within its continuing program aimed at addressing the over-all risk-reduction opportunity.

One mechanism for establishing priorities is technical consensus. A consensus prioritization of research opportunities could be established by convening a group of persons associated with:

a. EPA program offices, ORD, Regions, the states and SAB,

b. academia, research institutes,

c. regulated community,

d. pollution control industry, consulting engineers, and

e. public representatives.

Such a group would be organized and developed by allowing a period of exchange of ideas and views on risk-reduction research and priorities. Also, subpanels representing each interest group could be established with the leaders represented on the central group.

In addition to establishing priorities, the subpanels could be asked to predict the future, especially in terms of new or escalating problems; formal forecasting tools might be used.

2.4.3 Extramural and Intramural Research -- A strong extramural research program is essential to complement EPA's intramural program. In addition to the work being funded by EPA at existing university centers, EPA should utilize other university and private organization capabilities through an open competitive process.

This is critical for the continued development of innovative risk reduction strategies and will help provide the trained personnel necessary to implement risk reduction strategies.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 10 1987

OFFICE OF
RESEARCH AND DEVELOPMENT

MEMORANDUM

SUBJECT: Economic Successes in Risk Reduction Research

FROM: John H. Skinner, Director
Office of Environmental Engineering
and Technology Demonstration (RD-681)

TO: Risk Reduction Work Group

As requested at the November 24, 1987, meeting of the Risk Reduction Work Group, attached are several examples of cost savings that have resulted from EPA's research program on innovative treatment technologies in the wastewater and hazardous waste areas. I am looking forward to meeting with you again at the December 17 meeting in Cambridge.

Attachments

cc: Kathleen Conway
Tom Devine

EXAMPLES OF COST SAVINGS FROM RESEARCH AND DEVELOPMENT

ON INNOVATIVE TREATMENT TECHNOLOGIES

EPA has conducted considerable successful research in the area of innovative treatment technologies. The application of these technologies can result in improved treatment effectiveness, risk reduction, and savings of energy and costs. The following are a few examples of such savings in the areas of wastewater and hazardous waste treatment.

Secondary Clarification Improvements. In the previous two decades, EPA and its predecessors funded research which developed improved secondary clarifiers for wastewater treatment plants. These secondary clarifiers incorporated flocculator center wells. A mildly stirred flocculation area was set up between the aeration basin and the secondary clarifier. The first full-scale testing of this new flocculation concept was conducted at the City of Corvallis, Oregon, which succeeded in producing an average effluent SS and BOD of 5 mg/1, which was equal to or better than that obtainable by using costly effluent filtration.

A $70,000 expenditure for basic research in flocculation has saved millions of dollars in construction and operating costs. For one 50-mgd plant, the original research has a benefit-to-cost ratio of 27 to 1. The potential national cost savings are in the order of $380 million, a benefit-to-cost ratio of 1400 to 1.

Improvements in Trickling Filter Design. EPA played a key role in the development of the trickling filter/solids contact process. An effluent SS and BOD of 10 mg/1 can be achieved without using effluent filtration. This provides a cost effective way of upgrading trickling filters with solids contact units to meet the national secondary treatment requirements. This process has been applied at over 50 locations across the country. By FY 1986, 17 projects had been funded under EPA's Innovative/Alternative program.

EPA's expenditure of $290,000 in conducting plant-scale testing of this process could result in a national savings of $280 million, which is equivalent to a benefit-to-cost ratio of 1000 to 1.

Oxygen Aeration Systems. Utilization of oxygen aeration for activated sludge treatment has received wide field acceptance. The R&D program moved a 20-year old concept through the pilot stage to a fully demonstrated capability by means of in-house effort, development contract and demonstration grants in a period of 5 years. Several cost effective systems for dissolving and utilizing oxygen gas have been developed. Based on the original EPA demonstrations, comparative costs for air and oxygen systems show average savings in total treatment costs of about 20 percent. A Federal R&D investment of $3.2 million has effected an annual savings of $14 million in treatment costs—a return on investment of 330 percent.