BUILDING A RESEARCH FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

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The purposes of this paper are: (1) to provide an overview of the programs of EPA's National Center for Environmental Research and Quality Assurance; (2) to discuss the role of science in environmental protection and (3) to provide specific information on water-related research we sponsor.

ABOUT EPA'S NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH AND QUALITY ASSURANCE

EPA's National Center for Environmental Research and Quality Assurance (NCERQA) was established in May 1995 as a part of the reorganization of EPA's Office of Research and Development (ORD). EPA research aims to generate the scientific knowledge and tools needed to support sound environmental decision-making today, and to help the nation better prepare to meet the environmental challenges of tomorrow. To these ends, we, in ORD conduct internal research through our own laboratory programs, and also support the work of external researchers through grants, fellowships and other kinds of support. As the principle source of ORD support for research conducted outside of EPA, NCERQA is pursuing a mission of inspiring and supporting the best possible quality science relevant to environmental problems that are of greatest importance to the nation and that are related to EPA's mission of protecting human health and the environment. We are dedicated to more fully integrating environmental research done in U.S. universities and non-profit institutions with EPA's own research programs.

This paper focuses on research supported through the principle water-related components of our competitive "Science to Achieve Results" (STAR) research grants program, and through some graduate fellowships. (In addition to these programs, NCERQA provides funding and oversight for some dedicated centers for specialized areas of research, which are noted briefly below.)

NCERQA's operating principles and procedures include the following: 1) We emphasize our priority of achieving excellence in research by making thorough, unbiased peer reviews and an open, competitive process the cornerstones of our award selection process. 2) We work to support research in areas reflecting the nation's highest priority environmental protection needs by constantly updating information on research needs as articulated by representatives of EPA's and other government regulatory programs, our advisory councils, and public, private sector and academic partners. 3) We leverage resources wherever possible by forming partnerships on common federal and private sector research needs and issuing joint solicitations. 4) We are dedicated to communicating widely about on-going research and research results through workshops, seminars, state-of-the-science papers, public information reports and Internet access. 5) We believe that it is very important to assist in the development of the next generation of environmental scientists through graduate and undergraduate fellowship programs.

The STAR program has grown over the past four years, and now awards $110 million dollars annually for research grants and fellowships in environmental science and engineering (including related disciplines such as economics and decision science.) At present, we have made awards to over 200 colleges, universities and non-profit research centers in all regions of the United States. STAR is not meant to be a "stand-alone" research program driven by investigator-initiated proposals. While there is such a component to STAR, the bulk of the research is funded through targeted Requests for Applications (RFAs). The RFAs focus research on areas of particular importance to the Agency that complement the ORD intramural research program and the programs of our research partners. NCERQA receives approximately 3000-3500 proposals each year for research and graduate fellowships. In 1997 the program awarded 173 EPA grants, 34 grants in partnership with

other agencies, and 116 graduate fellowships. Recipients were 156 institutions and organizations in 44 states, the District

of Columbia and Guam. On an annual basis, NCERQA administers 500-600 research grants and some 300 fellowships.

The STAR Program also supports research at four national Centers of Excellence, each focusing on long-term, multi-disciplinary research in research areas of broad concern to EPA. These are: the Center for Ecological Health Research at the University of California at Davis; the National Center for Clean Industrial and Treatment Technologies at Michigan Technological University; the Multiscale Experimental Ecosystems Research Center at the University of Maryland Center for Environmental Studies and the Center on Airborne Organics at the Massachusetts Institute of Technology. Other NCERQA programs include: the Small Business Innovation Research program; the Hazardous Substance Research Center (HSRC) program, with locations in five places throughout the U.S.; the Experimental Program To Stimulate Competitive Research (EPSCoR); the Culturally Diverse Academic Institution Program; the AAAS Science and Engineering Fellowship Program and the Resident Research Associateship Program.

STAR Partnerships with other funding organizations have expanded greatly in the past three years. In 1995, there was one STAR partnership program with NSF, supporting joint competitions in three research areas. The number of partners has now grown to twelve, and includes private sector organizations as well as federal agencies. The resulting leveraging of funds allows about 20 percent more money to be awarded to researchers than would have been possible with EPA resources alone.

THE IMPORTANCE OF SOUND SCIENCE IN ENVIRONMENTAL DECISIONS

The quality of the science underpinning our work is critical in ensuring that EPA's regulatory and non-regulatory programs are received by the public and the regulated community as fair, technically sound and appropriate to accomplish the goals set forth by Congress and the public. For EPA, the credibility of science is becoming a greater focus of attention all the time. Regulations are being required to become more performance based, and cost/benefit methods are being scrutinized and refined. The science related to such issues has already become something of a battleground, and promises to be more so in the future. There will be a greater focus on understanding environmental risks and risk reduction vs. perceptions of environmental values. Regulations are also becoming more oriented towards multi-media approaches, to avoid the gaps in environmental protection that can result when one environmental medium is considered independently of others. Multimedia impact assessment approaches are also critical to improve the efficiency with which regulated entities and EPA deal with one another, because facilities often must meet regulatory requirements addressing multiple types of environmental release. Multi-media approaches are an important improvement, but they pose more complex technical questions about assessing, priority-ranking and reducing environmental risks.

Another changing aspect of environmental regulation is that communities are becoming more involved in regulation development and implementation, with "right -to- know" requirements often playing a critical role. Again, this requires some new orientations for science, for example in how to communicate research results most clearly to lay audiences. And, to some extent the scientific questions being asked are changing, for example with less emphasis on chemically oriented issues and more on ecological and biological constraints in dealing with water quality issues.

Finally, high quality science is needed to help EPA and all federal agencies meet new requirements for accountability and results-based performance measurement. Federal agencies are now mandated to carry out all their activities, including research, under a new law called the Government Performance and Results Act (GPRA). Simply stated, this requires agencies to follow an outcome and goal oriented approach, reporting results of all their work in terms of accomplishments achieved, rather than just activities undertaken. From the research planning and accountability perspectives, sound science will be essential to helping us effectively meet the requirements of this Act. Since we will be faced with a greater degree of accountability, high quality scientific outputs will help us deliver better performance measures to help evaluate the results of our work, while simultaneously addressing fundamental problems in environmental science.

WATER-RELATED RESEARCH SUPPORTED BY NCERQA

STAR Research Addressing Drinking Water Issues

The 1996 SDWA Amendments emphasize the need for the best available, peer-reviewed scientific approaches in

making decisions regarding the safety and treatment of drinking water. To support this need, EPA's major external research program, Science to Achieve Results (the "STAR program") allocates funds to research regarding microbial pathogens, disinfection byproducts (DBPs) and other emerging problems. Additionally, contracts have been let through EPA's Small Business Innovation Research (SBIR) program. The grants funded thru the STAR program are generally awarded for three-year time periods. On-going research is summarized below:

Cryptosporidium Research

Cryptosporidium parvum is the pathogen that caused illness in over 400,000 people in Milwaukee in 1993. Contamination of the city's water supply was undiscovered for at least two weeks because a resting stage (oocyst) form of the microorganism survived a disinfection process and remained undetected in the water supply. *Cryptosporidium* oocysts may be present in fifty percent or more of the surface waters in the U.S. and are highly resistant to chlorination. Ingestion of a small number of viable oocysts may cause illness in otherwise healthy individuals. Four research projects on *Cryptosporidium* are being supported by STAR grants. The Metropolitan Water District of Southern California is developing an assay to identify infectious oocysts from environmental samples of *C. parvum*. A method to monitor oocyst survival will help to ensure that disinfection processes have been effective. An investigator from Kansas State University will construct DNA libraries for various species and subgroups of *Cryptosporidium*. These will be made available to other investigators, supporting consistency of results, and providing *Cryptosporidium* genetic information for research across the country. St. Luke's Hospital and the University of Texas are studying whether *Cryptosporidium* from different regions differs in virulence (affecting how many people become ill and the severity of the illness). Volunteer humans and mice are evaluated to determine the typical infectious dose, and to evaluate individual responses. In addition to assessing virulence in *Cryptosporidium* from different sources, results are expected to aid in diagnosis of infected people. Ohio State University is using test animals to study the virulence and infectivity of *C. parvum* isolates known to be infectious to humans.

Other Microbial Contamination Studies

Researchers at the University of North Carolina at Chapel Hill are working with human volunteers to study infectivity of two viruses, Norwalk virus and Snow Mountain Agent. They will examine immune responses of individuals most susceptible to infection, and evaluate models of dose infectivity. Results will help to refine risk assessments and establish safe exposure limits.

The 1996 SDWA Amendments require disinfection of groundwater used as a drinking water source unless "natural disinfection" can be demonstrated to occur. Researchers at the University of California and the Baylor College of Medicine are using recombinant Norwalk virus particles to evaluate natural disinfection processes. Preliminary data suggest pH may be a critical factor. Results of this research will be relevant to establishing set-back distances between potential contaminant sources and intake points. And findings relevant to enhancing natural bacterial activity may aid *in situ* bioremediation of contaminated ground water.

The New York State Department of Health and the U.S. Geological Survey are evaluating field methods to measure bacterial activity by monitoring oxygen consumption. Preliminary results indicate low bacterial respiration rates in the aquifer, which indicates that introducing oxygen is probably an effective way to speed up natural bioremediation. Another preliminary study by El Paso Community College and Texas A&M indicates that viruses can exist in groundwater in a "reversibly inactivated" state, unable to cause infection until reactivated. This may explain contradictory results in testing effectiveness of disinfection procedures. This study will investigate inactivation mechanisms and environmental factors that could promote or retard reactivation.

The University of Arizona is developing a combined cell culture/PCR technique for enteroviruses from sewage. This technique, combining advantages of the two approaches, is expected to be sensitive and cost-effective. Fecal coliform contamination of source waters is monitored with tests that do not distinguish human from animal and other sources of coliform bacteria. As the presence of fecal coliforms could indicate a risk of human infection, water filtration and/or disinfection are required as a precaution. Information on human risks from domestic livestock wastes is inconclusive, so that equal degrees of treatment are needed if livestock wastes are present. However, there are also common non-livestock-related coliform sources not associated with human risk factors. In preliminary studies, the University of North Carolina has developed techniques for distinguishing human fecal contamination from that of wildlife. These investigators have received a STAR grant to refine a methodology to assist in monitoring source waters more accurately for potential public health risk.

Socio-Economic Study of Protecting Upstream Water Sources

Cornell University is assessing public opinion on watershed protection issues, based on interviews with upstate New York residents, and with New York City residents whose drinking water comes from the watershed. Results will provide information relevant to the public process by which the City, other local governments, the State and the U.S. EPA assess options for protecting water quality in the watershed.

Research Concerning Disinfection By-products (DBPs)

Health Effects Studies

The potential for cancer-causing effects of trihalomethanes is being evaluated through rodent studies at the Medical College of Ohio. The University of Illinois at Urbana-Champaign is evaluating the pros and cons of using of mammalian cell cultures rather than bacterial genotoxicity tests to predict DBP risks. Investigators at Pacific Northwest National Laboratories theorize that small amounts of haloacetates are easily removed from the human system, but ingestion beyond a threshold amount results in inactivation of the enzyme necessary for this detoxification. Rodents and human liver cell cultures will be used to study whether enzyme inactivation occurs, where haloacetates are distributed in the body after ingestion, and how they are eventually eliminated. It is hoped that elucidating the mechanisms of trihalomethane absorption and elimination will support more accurate hazard assessments for human haloacetate ingestion.

Exposure Studies

Human exposure routes to tap water DBPs include drinking, inhaling volatile DBPs in showers and baths and dermal exposure. The University of Medicine and Dentistry of New Jersey is assessing the relative importance of dermal absorption and inhalation as exposure routes for haloacetic acid DBPs. Investigators from the University of Texas Medical Branch are trying to identify halogenated acetonitrile "biomarkers", for use in assessing exposures and identifying affected tissues. The University of North Carolina at Chapel Hill is studying the chemical nature and metabolite formation of haloacetic acid DBPs with an eye to identifying biomarkers (typically molecules or portions of molecules serving as "tags" to demonstrate that an organism has been exposed to a particular chemical). Haloacetic acids may form macromolecular adducts that could serve as biomarkers.

Detection Methods

The recently proposed revised drinking water standard for the carcinogen bromate sets a threshold level at which good detection methods are not widely available. Relevant to this need, the University of North Carolina at Chapel Hill has received a STAR grant to evaluate a cost-effective ion chromatographic system for detecting oxyhalides (bromate, iodate and chlorite) using UV spectrophotometry. Pennsylvania State University is developing precise, low-cost methods to measure haloacetic acids, using a technique called "surface enhanced Raman scattering." This method requires a minimum of expertise and is practical for regular use in treatment plants. The University of Massachusetts is developing and refining analytical methods for ozonation disinfection byproducts.

Improved Disinfection Processes

A team from the Universities of Washington and Colorado is developing a method to reduce the amount of metal coagulant used for removal of natural organic matter and particles from drinking water. A graduate fellowship has been awarded at Michigan State University for investigation of methods to reduce DBPs from ozonation and for biological treatment of naturally occurring humic substances. This study will examine modifications of humic substances during ozonation, the biodegradability of byproducts, and the formation of organochlorine compounds during chlorine disinfection. The University of Michigan and the Hebrew University are analyzing DBPs from a secondary disinfectant formulation using hydrogen peroxide and silver, focusing on potential use of the method in long-term residual disinfection. Finally, the University of Colorado at Boulder is studying softening and coagulation treatments to remove DBP precursors and arsenic.

Other Toxic Chemical Risks

The University of Kentucky and Purdue University are evaluating brain accumulations of aluminum from drinking water, based on rat studies of oral bioavailability, aluminum circulation and elimination from the brain. Princeton University is studying the role of microorganisms in arsenic cycling in contaminated water. Investigators propose that bacteria convert one form of arsenic into another more mobile form, and also

catalyze precipitation of arsenic sulfides. Results should help refine assessments of human exposure and hazard from arsenic contamination.

Small Business Innovation Research (SBIR) Funded by EPA

The SBIR program takes advantage of the talents of small businesses to find solutions to priority environmental problems. Proposals funded under the SBIR program must fit into EPA's overall research strategy, within announced research areas, several of which may include drinking water research and development needs. The use of Raman scattering on small water samples to identify viable contaminants, including cysts and oocysts, is being investigated by Maine Research and Technology. SymBiotech is developing a simple-to-use biosensor intended to reduce the cost and increase the ease of detecting *Cryptosporidium*. Media and Process Technology is investigating long-term operational stability, system optimization and operating economics of a one-step ceramic membrane filtration process designed for small and mid-sized treatment plants.

Demonstrating that zeolite molecular sieve membranes are practical for removal of trihalomethanes and other impurities is the primary objective of a study by TDA Research, along with improvements in zeolite film fabrication and measuring water flux. Humate and fulvate precursors to DBPs can be almost completely removed from chlorine treated drinking water using some inexpensive inorganic materials as exchange media. Additional work has shown that these materials can also catalyze decomposition of haloacetic acid DBPs. Universal Fuel Development Associates have received an award to refine this work and determine if removal rates of DBP precursors or haloacetic acid DBPs are competitive with current removal technologies.

The Nitrate Elimination Company has demonstrated the feasibility of using immobilized enzymes to remove nitrates from drinking water. Using phase II funding, they will refine catalyst use and production, and work towards designing a commercially ready reactor. ICET is conducting research on producing new, highly hydrophilic sorbent materials for lead removal under various water source conditions. They are seeking to improve the ability to control coagulant chemical dosage under circumstances of highly variable raw water quality. Clear Corporation Enterprises is refining a coagulant control system that would require less time and labor and be more sensitive in providing dose control data.

OTHER WATER-RELATED STAR RESEARCH SUPPORTED BY NCERQA

Ecosystem Indicators

Research grants in this area support developing and evaluating ecological indicators, suites of indicators, indices or models of use in characterizing status and trends in the condition of ecosystems. This work emphasizes indicators with the potential to improve our ability to characterize ecological integrity and sustainability, to improve confidence bounds on such assessments, and to provide reasonable scientific conceptual models of the functional relationship between ecosystem conditions and anthropogenic stressors. The RFA emphasizes the need for some indicators that can reflect impacts across types of ecosystem, as well as those that may help to integrate data gathered on multiple spatial scales, or based on a variety of sampling regimes. A recent area of emphasis is on indicators using molecular biology techniques that would allow measurements of genetic diversity on interspecies and intraspecies levels.

Contaminated Sediments

Our contaminated sediments research area includes field validations of sediment quality criteria, test methods, and models for determining and assessing ecological effects of sediment contamination. Methods may include biological community structure indicators, bioassays, chemical assays, and ways of combining these, for a range of contaminant types and physico-chemical background conditions.

Ecology and Oceanography of Harmful Algal Blooms

This multi-agency RFA focuses on understanding the causes of harmful algal blooms, the effect of such blooms on food web and fisheries, and the development of an enhanced predictive and early warning capability for their occurrence and impact. Studies will include the initiation, distribution, and accumulation of individual bloom-forming species and the physiological and biochemical bases of toxin production. Of particular importance is information about anthropogenic and natural drivers of the biophysical mechanisms that facilitate and regulate harmful algal blooms. Attempts are being made to develop predictive models to help implement early warning or intervention approaches for responding to these phenomena, which can have severe health, ecological and economic impacts.

Ecosystem Restoration

EPA and the National Aeronautics and Space Administration are jointly supporting this RFA for research addressing fundamental concepts of ecosystem rehabilitation in the context of larger watersheds. The following questions are of particular interest: (1) What characteristics and functions of ecosystems are most amenable to being restored/rehabilitated from specific environmental insults, and how can the degree of restoration be evaluated and monitored? (2) Can improved knowledge of basic ecosystem processes improve the success of rehabilitation programs/projects, and how can realistic rehabilitation/restoration goals and priorities be set on the basis of process-level understanding? (3) How can we set restoration or rehabilitation goals and approaches that best integrate environmental and economic priorities?

Health Effects of Arsenic

Sponsored by EPA, the American Water Works Association Research Foundation (AWWARF) and Association of California Water Agencies (ACWA), this RFA is requesting research on the health effects of low levels of arsenic in drinking water, focusing on total arsenic intake, mechanisms of arsenic toxicity and epidemiological studies related to cancer and other health endpoints.

Partnership with the National Science Foundation for Water and Watersheds Research

Under a Partnership for Environmental Research, EPA and the National Science Foundation (NSF) are jointly supporting a program of multidisciplinary, fundamental research on key scientific, engineering, and socioeconomic questions for understanding, protecting, and restoring water resources and watershed processes in the U.S. and other regions of the world. Investigators are encouraged to bring together cross-discipline approaches to address watershed-scale issues. Most of the projects include data analyses from a full range of natural science disciplines, including aquatic chemistry, geology and biology, considered in the context of data on economic or socio-cultural conditions that are influencing or will influence sources, pollutant loads and resulting ecological stresses throughout subject watersheds.

COMMUNICATIONS

EPA is placing a very high priority on communicating about on-going and completed research within the STAR program with a full spectrum of academic and industry researchers, policymakers at federal and other levels, lawmakers and the public. We are taking advantage of the widespread Internet access among the academic community to ensure that all new RFAs and fellowship announcements, and follow-up information on scheduling of reviews and award announcements are quickly available to interested researchers via our Website (**www.epa/ncerqa.gov**). The Website includes a comprehensive archive of abstracts of research funded since 1995, cross-referenced and searchable by investigator, topic and institution. Over time, it will provide references and summaries of final reports as research is completed. Of course, RFAs are also announced in a full range of academic journals as well as via the Internet, and hard copies of all RFAs are available by mail from NCERQA.

To summarize on-going research for those who are not specialists in particular research areas, we are preparing a series of short summary reports ("STAR Reports"). These are designed for government or academic readers, or informed lay readers, who are interested in obtaining snapshots of the work supported in specific research areas. These reports are also available at our website.

To allow researchers and other interested parties to exchange detailed information about on-going research, particularly to support cross-fertilization of ideas among researchers and potential users of their findings, we support progress review workshops on specific research areas on an annual or biennial basis. Workshops to date in the areas of "Water and Watersheds," "Hydrologic Vulnerability to Climate Change," "Decision Making and Environmental Policy" and "Ecological Assessments and Indicators," among others, have been very successful at bringing together people with interests in water resource science and management, including representatives from EPA, other federal and state agencies, academics and industry researchers and graduate and undergraduate students. Information on obtaining copies of workshop reports, STAR progress reports, or specific information on research projects can be found via the Website by identifying EPA staff contacts responsible for major research areas.

COMBINING SOUND SCIENCE WITH RELEVANCE TO HIGHEST PRIORITY NEEDS

NCERQA bases its research programs on the following key principles: partnerships, leveraging, strategic planning, risk analysis and risk reduction, harmonizing,

technical assistance and support, knowing our customers, accountability, sound science, peer review, communications and quality assurance. As we make the transition into the next century we are grappling with the policy issues outlined in this Issue's theme, including increased delegations of responsibility from federal to state and local governments, multi-media environmental assessments, increased community involvement, and dealing with resource limitations. We also face increasing needs to integrate across disciplines, pollutants and geographic and political boundaries. At EPA, we feel strongly that scientific research that is simultaneously relevant and of unimpeachable quality must be the cornerstone of an effective environmental research program for the future. We believe that, as discussed in the theme introduction, the peer review process must not be one in which researchers are perceived to be talking only to themselves. Given the proper structure and procedures, we feel the review process can incorporate the pure "quality of science" concerns that can only be addressed through unbiased peer review, and the questions of potential relevance of research areas to the nation's priority environmental protection needs. Based on comments received from academia and other grant-making agencies and organizations, we feel hopeful that our grant review and selection process is doing well at accomplishing these joint needs. We are very impressed with the quality of research proposals that have been submitted and selected for funding to date. We look forward with great anticipation to research findings that promise to make important contributions to the fundamental understanding of aquatic ecosystem processes, and to helping the nation better manage water resources for long term ecological and human health and ecosystem sustainability.

BIOGRAPHICAL SKETCH

Peter W. Preuss, is Director, National Center for Environmental Research and Quality Assurance, Office of Research and Development (ORD), U.S. Environmental Protection Agency. This Center was created in 1995 and is responsible for the ORD extramural research program of grants, fellowships and university centers. It is also responsible for agency-wide oversight of quality assurance and peer review.