Water Research Institute

Annual Technical Report

FY 1998

Introduction

Research Program

Maine is the 'blue water' state as described by final report of the Great Pond Task Force in 1997, a reference to the clean, clear, oligotrophic condition of many of our surface waters. However, our water resources are not problem-free. Indeed, as the visible condition of previously impacted waters has improved during the past three decades, we have become increasingly aware of invisible impacts such as mercury, dioxin, arsenic, and acid rain. The Maine Water Research Institute is a central player in the overall research program to address these and other issues in Maine. 1998 was the last year of the USGS WRRI regional competition. All three of the proposals submitted by Maine in 1998 were funded, and indeed were ranked 1, 2 and 4 by the regional panel. These projects, plus the two proposals funded in 1997, comprised the USGS-funded research program of the Institute in 1998. These projects are summarized below. We are particularly pleased to report that three activities of the WRI involved collaboration with social scientists. The largest effort is the project by Kevin Boyle (UMaine) and John Halstead (UNH) on valuations of lake front property. The second is our EPA/NSF Water and Watersheds grant which closely involves the University of Maine Smith Center for Public Policy (see 'Oher Institute Research' below). Finally, the WRI secured the funding and participated in a graduate student project and publication on the contributions of Maine lakes to the state economy (Boyle et al, 1997 in the 'Reports' section). Other Institute research in 1998 included the following: · Collaborative Research on Maine Surface Water Toxics (NSF 1996-98 $298,000 to Kahl, Katz, Courtemanch (DEP), and Bushway; and Maine DEP 1996-98; $740,000 to Kahl, Katz, and Bushway). The Maine Surface Water Ambient Toxics (SWAT: LD 1042) Program, initiated in 1994, is designed to determine the extent and magnitude of toxic contamination in Maine surface waters. The overall program involves fish and sediment monitoring for toxic substances, and other special studies as suggested by data collected. This cooperative agreement between DEP and the Institute provides analytical support for SWAT and the related Dioxin monitoring program in Maine, and provides new input from University of Maine researchers who have substantial expertise in Maine with the environmental chemistry of these compounds. This project constructed new 'clean room' facilities necessary to conduct low-level organic toxic and heavy metal analyses, and acquired the instrumentation to analyze for trace level organic toxic compounds. The facilities expanded the existing inorganic WRI laboratory capabilities to create a state-of-the-art organic and inorganic environmental research facility for the State of Maine. · Long Term Monitoring of Maine Lakes and Streams (EPA, 1991-99; $680,000 to J.S. Kahl and S.A. Norton). The University of Maine was a founding participant in the EPA LTM program begun in 1983. The program has expanded in recent years to include spring sampling of outlets on selected lakes, and now includes lakes sampled in the 1980s by the High Elevation Lake Monitoring project conducted by Kahl and Matt Scott of Maine DEP. · Surface water data analysis, Environ. Monitoring & Assessment (EPA 1992-98; $960,000 to J.S. Kahl and S.A. Norton). Since 1991, the WRI laboratory has bee the national surface water chemistry laboratory for the EPA flagship monitoring program EMAP. Activities of this project have included modifying new analytical methods for total nitrogen and aluminum speciation, developing interpretative methods for data validation and assessment, and publishing regional statisitical data in conjunction with EPA scientists. · Development of a Water Resource Management Plan, Acadia N.P. (NPS, 1994-98; $66,000), to Kahl and Houtman. A comprehensive plan does not

exist for management of water resources in Acadia National Park. The 1990 Acadia General Management Plan identified a Water Resources Management Plan (WRMP) as an important part of future management efforts. Kahl and Houtman were funded in 1994 to develop a WRMP to guide management of the lakes, ponds, streams, and groundwater into the next century. An Oversight Committee was assembled to review progress and provide input to the plan. Committee members included local town admin-istrators, business people, MDI water suppliers, and staff from several state agencies. We solicited public input, and sent out a questionnaire to interested persons to help identify key issues. A series of focus group meetings in the win-ter provided forums for various state and local interest groups to discuss their con-cerns. We have reviewed literature and documents pertaining to Acadia water resources. A complete draft of the plan will be available in 1999. · Linking watershed-scale indicators of changes in atmospheric deposition to regional response patterns. (EPA, 1997-2000, $636,000 to Kahl and 7 others). This research is part of a program addressing scientific and societal needs by invest-igating the processes and indicators of response and recovery at the Bear Brook Watershed in Maine (BBWM). We are using the geochemical model MAGIC to predict site specific results and will then scale the results from BBWM to the regional level by re-examining the parallel spatial and temp-oral chemical trends in the High Elevation Lakes in Maine (HELM) and their watersheds. These lakes had the highest concentrations of nitrate of any known lake population in the northeastern US in the 1980s. Concurrently, we are developing the mechanisms to present these findings in a practical format for state and federal resource managers and decision-makers, guiding them to information relevant to their goals. This latter objective is especially relevant in Maine, because of the importance of the forest products industry to the state economy. This information is fundamental for EPA to meet the Congressional mandate in the Clean Air Act Amendments (CAAA) to ascertain trends in ecological response, and to determine the effectiveness of the CAAA in influencing these trends. Site specific data from BBWM scaled to the regional HELM population will also provide a template for the recognition and under-standing of possible N-saturation and base cation depletion that may be occurring in watersheds in the region. This information will be presented and evaluated for use in management and policy decisions by industry, and at the local, state and federal level. · Inferring regional patterns and responses in N and Hg biogeochemistry using two sets of gauged paired-watersheds (EPA, $475,000 to Kahl et al.). This project is part of long-term ecological research using two gauged-watersheds to be imple-mented at Acadia National Park through collaborative funding by USGS and this proposal to EPA. The focus is atmospheric deposition of N and Hg, and their ecological consequences. Both elements are of major concern, both regionally and to the Park Service at Acadia. This location offers the advantages of a) co-funding for cost-effectiveness; b) a natural experimental design for the two watersheds because of a major forest fire in part of the Park in 1947; c) parallel design with the acidic deposition experiment on paired-watersheds at the nearby Bear Brook Watershed, Maine (BBWM); and d) prior research at Acadia and BBWM that supply background data, and provide the basis for ecosystem indicators to be applied at Acadia. Our objectives are addressing N cycling and saturation, and Hg input and bioavailability, in paired watersheds with different forest types. We are using the natural landscape contrasts provided by fire to compare patterns and processes in N and Hg sequestration and mobility. N loading to estuaries is being addressed by periodic sampling of estuary tributaries as ‘satellite’ locations, whose N-loading will be extrapolated from occasional sampling by using the more intensively monitored main watersheds as index sites. The results will provide new information for Acadia and for the New England region on the ecological consequences of high N deposition at Acadia, and the loading of N to estuaries in the region. We lack an explanation of the high accumulation rates of Hg in sediment and peat cores compared to wet-only deposition, and have not explained why Acadia has some of the highest Hg concentrations in biota in the world. The general repres-entativeness of Acadia forests for the New England region, combined with the fire history to be included in our experimental design (fire also being ‘typical’ of the historical New England landscape), offers the opportunity to understand some key issues for Acadia, while providing insight into these issues at the regional scale.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	PEARL: Public Educational Access to Resources on Lakes in Maine
Project Number	
Start Date	09/01/1997
End Date	08/31/1999
Research Category	Water Quality
Focus Category #1	Education
Focus Category #2	Water Quality
Focus Category #3	Water Use
Lead Institution	University of Maine

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Mary Beard-Tisdale	Associate Professor	University of Maine	01
Jeffrey S. Kahl	Associate Professor	Water Research Institute	02

Problem and Research Objectives

Project Objectives With over 5700 lakes and ponds in Maine (Williams, 1998), and with different local and state agencies charged with collecting and distributing lake data, it is often difficult for scientists, educators, and community organizations to find related information. Untimely, inaccurate, and incomplete data can be reduced by storing lake data-sets in one location and distributing them over the Web. PEARL was designed to serve this need, in addition to assisting with public education on water conservation and natural resource issues. The Internet is on its way to becoming the primary platform for GIS, where data publishing, display, and query have been most successfully implemented (Longley, et. al., 1999). Yet the Internet presents its own problems; slow connections, interface restrictions, and browser incompatibilities compromise the utility of PEARL for many people. An alternative, stand-alone method of accessing Maine's lake data is being developed for distribution on Compact Disk.

Methodology

Methods We used ESRI Arc/View GIS to spatially join statewide lake information in a standard database format (dbf), to an extensive statewide lake polygon layer. The subsequent theme became the interactive search/display layer for a server side application created with Microsoft (MS) Visual Basic and ESRI MapObjects (ESRI, 1996). Additional lake data was stored in relational databases using MS Access. MS FrontPage was used to create a WebSite that serves this Visual Basic / MapObjects application to the client (individual users). By using Active Server Pages-which combine HTML code and vbscript that contain structured query language statements (SQL)-we provided visual- and text-based search tools that allow access to the lake data. Lake data consists primarily of secchi depth

measurements (Williams, 1998). Some phosphorus and trophic data are available. Data were gathered and compiled by the Water Research Institute, the Volunteer Lake Monitoring Program, and Department of Environmental Protection. All data are available to the user in text format, and secchi data are also available through an interactive graphing tool using ChartFx by SoftwareFx. This program has proved problematic in our configuration and a substitute method for graphing is being devised.

Principal Findings and Significance

Principal Findings 1. The site has been beneficial to scientists, researchers, educators, students, lake monitors, and land developers. 2. Data can be accessed quickly and can be updated very efficiently. 3. The full utility of the site is not yet achieved -- new chemistry and biological data need to be compiled and incorporated. 4. It is a cost effective means for information access. 5. Internet interruptions, client incompatibilities with program components (e.g. ActiveX controls, default browser security settings), and user unfamiliarity with the site hinder PEARL's effectiveness. Future Work Revisions and data additions to the WebSite are ongoing, as is the development of a separate CD ROM application to provide the same, or better, tools in a stand alone environment. 1. Current tools (especially ESRI MapObjects and MS Visual Basic) will be used to create an interactive CD application. A prototype is available of the Mount Desert Island region (not yet on CD). 2. Addition of new data layers (e.g. soils, vegetation) to Web and CD. 3. New educational tools and links for elementary through college level. 4. Addition of links or communication space for VLMP members and Lake Associations. 5. Publication of VLMP reports and data summaries on the PEARL Web-site, and possible inclusion in CD application. 6. More complete documentation and metadata; online user instruction. This project provides an efficient means for different groups to gain access to an extensive amount of lake-data in Maine, and serves to educate the public about conservation and natural resource issues. It provides a tool for researchers to better understand the problems of using GIS over the Internet. Further research through PEARL may lead to new developments in applying the Internet as a means to support Web based GIS in a social, educational, and technical context.

Descriptors

Information Science, Water Chemistry, Public Education, Internet GIS, Social Sciences

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Tom Noonan, M.S. candidate in Spatial Engineering. Thesis: Explorary Spatial Data Analysis and Data Libraries, expected in 2000. Eric Herbert, M.S candidate in Water Resources. Thesis: Landscape controls of water quality in Maine lakes: a GIS analysis, expected in 2001.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Noonan, Tom, 1999. PEARL demonstration and exhibit. 1999 Maine Water Conference, April 15,

1999. Noonan, Tom, 1999. PEARL LCD slide presentation. Maine GIS Users Group. Eastern Maine Technical College, Bangor, Maine. Noonan, Tom, 1999. PEARL technical development and application issues. Atlantic Institute Meeting, Laval Universite, Quebec, PQ.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	A Study of the Effects of Lake-Water Quality on the Prices of Lake-Front Property in Maine, New Hampshire and Vermont
Project Number	
Start Date	09/01/1997
End Date	08/31/1999
Research Category	Social Sciences
Focus Category #1	Economics
Focus Category #2	Water Use
Focus Category #3	Management and Planning
Lead Institution	University of Maine

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Kevin Boyle	Professor	University of Maine	01
John Halstead	Associate Professor	University of New Hampshire	02
Roy Bouchard	Professional Staff	Maine Department of Environmental Protection	03

Problem and Research Objectives

The proposed research will estimate the impact of lake-water clarity on the sales prices of lake-front properties in New Hampshire and Vermont, and the impact of weed growth on sale prices of lake-front properties in Vermont. This research builds on a hedonic property value study funded by the Maine Department of Environmental Protection and the University of Maine Water Research Institute. A hedonic model is estimated using sale prices of lake-front properties as a dependent variable, which is regressed on property characteristics and a water quality variable (secchi disk measurements of water clarity) to statistically infer the implicit value of water quality. The research will address three of the priorities listed in the RFA. The research will model the interface between lake ecology and economic values, thereby providing a direct link between changes in water quality induced by non-point source

pollution and economic values. The economic value estimates can be used in public education efforts to convince community leaders and owners of lake-front properties that it is in their own economic interests to take action on their properties to protect lake quality. The estimates also can help to determine whether lake-protecion projects result in net economic gains to society and to prioritize what lakes should receive scarce resources for protection.

Methodology

The estimation of the hedonic price functions and demand for water clarity will follow the methods of Mendelsohn (1984; 1985). Hedonic price functions will be estimated by regressing property sales prices against property characteristics and environmental variables, notably water clarity and weed density. Data will be collected for ME, NH, and VT, expanding the original work of Boyle into the other northern New England states. Property sales data have been collected, and analysis of an owner survey is underway. The survey follows the methods of Dillman (1978). Analysis of the survey data combined with the sales data will be the final task in the project.

Principal Findings and Significance

There are no findings at this stage of the project. The significance of the results will be understood when the relationships are developed for NH and VT for property values vs. water quality. In Maine, previous work by Boyle and co-workers established that the value of shore-front properties were increased by $11 to $200 per foot of frontage when water quality was high. If this relationship is true for other New England states, then this will be another economic tool for environmental protection.

Descriptors

Water Quality, Eutrophication, Weed Growth, Property Values

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

An M.S. thesis program is underway by Tommy Hsu, student in the Ecology and Environmental Sciences graduate program. Completion expected in 2000.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Boyle, Kevin J., R. Bouchard and J. Schuetz. 1999. Economic Values and Economic Impacts of Nonresidential Users of Maine's Lakes. 12th Annual National Conference Enhancing the States Lake Management Programs: Nutrient Management Strategies for Lakes and Reservoirs, Chicago Illinois.
Boyle, Kevin J. 1999. The Effect of Lake Water Clarity on Recreational Uses of Maine's Lakes. Annual New England Lakes Conference - Promoting Awareness and Action for our Lakes Future. Auburn, Maine.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Differentiating Local Contributions of Mercury from Regional Inputs
Project Number	
Start Date	09/01/1998
End Date	10/31/2000
Research Category	Water Quality
Focus Category #1	Non Point Pollution
Focus Category #2	Toxic Substances
Focus Category #3	Water Quality
Lead Institution	University of Maine

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Stephen A. Norton	Professor	University of Maine	01
David L. Courtemanch	Professional Staff	Maine Department of Environmental Protection	02
Jeffrey S. Kahl	Associate Professor	University of Maine	03

Problem and Research Objectives

Technical Abstract Regionally, atmospheric deposition of Hg in Maine increased from background about 1900, reached a maximum between about 1970 and 1975, and has subsequently declined. These trends are recorded in dated lake sediment cores and dated bog accumulations. Recent surveys of concentrations of Hg in surface sediments and fish in Maine lakes indicate that lakes and fish near several point source emitters of Hg may be impacted by local deposition from these atmospheric emissions of Hg. We propose the collection, 210Pb dating, and chemical analysis of sediment cores from eight lakes and two bogs from sites spatially displayed around and at different distances from these point sources. We hypothesize, based on emission data and atmospheric modeling, that elevated atmospheric deposition of Hg occurred in a pattern related to these sources. The strength of the atmospheric deposition signal is modeled to be sufficiently strong such that comparison between the Hg flux to the coring site and the history of atmospheric emissions can be compared. Accumulation of Hg in catchments, and subsequent leaching to lakes, smears the historic paleolimnological record. These effects will be minimized by studying sediment from lakes with small undisturbed watersheds and through analysis of accumulated ombrotrophic peat. Regional and State Water Problems: The significance of mercury. Mercury contamination of biota is an international issue. The increasing awareness of the problem has resulted in fish consumption advisories in 38 states, many of them imposed in the past few years. The source of increased Hg is generally accepted to be from the atmosphere, as a consequence of combustion of fossil fuels, waste incineration, and industrial chemical

processes. These sources are an issue in eastern Maine and local deposition from them is the focus of this proposal. Emission sources for Hg may have a disproportionate local influence on water and biota. Because of the widespread occurrence of emitters, it is important to distinguish between regional and local pollution sources. The need for this research. Although the existing data on Hg in fish and surface lake sediments suggest (Land and Water Resources, 1997) that the local sources are having an impact on fish and sediment chemistry, other factors may play a significant role. These possible factors include local sources of geologic Hg, differences in Hg bioaccumulation caused by specific fish species, or certain physical and chemical lake characteristics. Analysis of 210Pb-dated lake sediment and peat cores will clearly indicate if the local sources are the explanation because we will see the increase in Hg accumulation in the sediment record at the time the sources commenced emissions. The cores will allow us to determine the historical impacts of the local sources, to test if these sources are important. The bog cores will enable a more accurate measure of the atmospheric deposition rate for Hg, free of distortion from sediment focussing and the lag time associated with accumulation and transport of Hg from the watershed to the lake. Statement of Results and Benefits: National and State significance of this project. Mercury pollution in surface waters and sediments and related high concentrations of Hg in fish have been identified problems for the northern tier of states from Minnesota to Maine for a decade (Engstrom and Swain, 1997; DEP, 1996; Norton et al., 1997). Although sources of Hg emissions are generally identified and enumerated (smelting, incineration, fossil fuel burning, industrial activity), their influence on local atmospheric deposition rates is not clear. Engstrom and Swain (1997) were able to descriminate between rural and urban sites, based on accumulation rates of Hg in lake sediments. Deposition of Hg has been monitored on a very local (100s of meters; Calasans and Malm, 1997) to intermediate distance (Steinnes and Krog, 1977; Gonzalez, 1991) using biological monitors. These studies clearly indicate depositional gradients away from the point source of pollution. Industrial facilities similar to those we hypothesize as being linked to local pollution are scattered across the country. Consequently, our findings will have broad applicability in the assessment of urban environmental impact from local or point sources of Hg atmospheric emissions. The 1998 WRRI 'call for proposals' in Maine specifically asked for projects that contributed to the needs of two agency programs: the federal USGS NAWQA or the state SWAT (Surface Water Aquatic Toxics). Projects involving SWAT priorities could include sources, fate, transport, and/or persistence of Hg, dioxin, PCBs, and/or pesticides in the environment. This proposal builds on existing SWAT data to investigate issues beyond the scope of agency resources. In addition, this project will collect information that may directly impact regulatory action, and result in reduction of Hg in the environment when the air emission licenses for the chemical plants and incinerators are revised. For example, the emissions from HoltraChem in Orrington, Maine (ca., an estimated 200 pounds per year in 1997; Land and Water Resources Council Report, 1997) are sufficient to account for all the Hg deposited annually in Maine in wet deposition. Pilot Mercury TMDL. The State of Maine recently submitted its list of water quality-limited waters as required in Section 303(d) of the Clean Water Act. These are waters that may require completion of a Total Maximum Daily Load (TMDL) analysis. In that document, it was noted that all of Maine's fresh waters have a fish consumption advisory due to Hg contamination and are therefore listed as water quality-limited. However, because the sources of Hg occur both within and from outside its jurisdictional borders, it was recommended that the U.S. EPA should conduct a TMDL analysis for Hg. The U.S. EPA has responded with interest to that recommendation and has proposed that a pilot TMDL for Hg be initiated for the Orrington, Maine area lakes. In addition to the local source deposition model developed by the Maine Departmental Protection Agency, U.S. EPA will estimate deposition from long range sources and the fate of these source terms in sediment and tissue. Data from the lake and peat cores, along with tissue data already collected for this group of lakes, will provide important empirical evidence for model evaluation (ground truth).

Methodology

The report on Fish Tissue Contamination in Maine Lakes (Mower et al., 1997, the REMAP study) found widespread high concentrations of Hg contamination in fish tissue throughout the state. This presumed contamination is attributed in part to Hg deposition from anthropogenic air emission sources within and outside the state. Initial review of that data suggested that there may be higher contamination in lakes east of Penobscot Bay (Figure 1). Three significant air contamination sources of Hg are situated next to the Penobscot estuary. Consequently, interest was focused on the contributions of local emission sources of Hg. However, the lakes were distributed at different distances and directions from the local emission sources. Furthermore, different species and size classes of fish were included in the study, making comparisons among lakes difficult, and potentially spurrious. Therefore, a second study was conducted that focused on determining if lakes are measurably affected by small local sources of Hg. This study used a targeted sampling strategy, rather than the randomized approach used in REMAP, and employed a more standardized sampling design. Two data sets were compared. The REMAP data provided comparative sediment Hg, and Hg concentrations of fish filet composites for those lakes where white perch were sampled. White perch were collected in 18 additional lakes outside of the modeled area (centered on Orrington, Maine) and individual filets were analyzed. Sediment: Surface sediment data are presented in Figure 2 which presents all the lakes arranged in increasing Hg concentrations for surface sediment. Lakes in the Orrington-Bucksport area (in red) are above the 42nd percentile of sediment Hg concentrations from a random population of lake surface sediments. This distribution suggests that these lakes may receive greater Hg than much of the Maine lake population. A T-test on the means of the two populations was significant ($r = 0.07$). Alternatively, lake basin morphometry or catchment characteristics may have resulted in or contributed to these elevated concentrations. While the data suggest that the HoltraChem/PERC complex may contribute extra Hg to the sediments of these lakes, this cannot be concluded with any certainty. Other sources need to be evaluated. Preliminary review of available geologic data suggests that bedrock in the South Orrington - North Bucksport area is not likely to be a significant source of Hg for aquatic life and lake sediments. The majority of this area is underlain by the Passagassawakeag Gneiss, an amphibolite-facies quartz - plagioclase gneiss locally containing sillimanite and garnet. Most other lithologies in this general area have been metamorphosed to a similar grade. These rocks underwent high-grade metamorphism in the Silurian, and retrograde metamorphism in the Devonian (Osberg et al., 1985). Mercury-bearing ore bodies, or Hg-bearing metasedimentary rocks, could not have retained a significant amount of the metal at the metamorphic grades in this area. Post-metamorphic mineralization of local rocks is possible, but no data indicate occurrences of Hg in these rocks. Fish tissue. Composite samples of white perch from the Orrington-Bucksport group of lakes were compared to white perch composites from the REMAP study. The Orrington-Bucksport fish were processed individually, then the results of both studies were combined for this analysis. Regression analysis combining these two data sets found that fish tissue concentrations of Hg were highly correlated with fish length and with lake location ($r<0.05$, $r = 0.7$). Although this relationship inferred that the Orrington-Bucksport fish populations may be different in their Hg concentrations, there were only nine lakes outside the Orrington area for comparison in the analysis. Also, the composites used in the REMAP study included fish of considerably different size. Size and age are important factors in determining Hg concentration. A second data set was collected from 18 lakes in Maine. It provided individual fish data, (i.e., specific size and Hg concentrations for each fish, $n = 242$). This approach removed the error associated with using an average size and an average Hg concentrations for each composite sample. The median Hg concentration is noticeably higher for the Orrington-Bucksport lakes population. A T-test on the means was significant ($r<0.001$). The difference between the means (0.31 mg Hg/kg) is greater than the concentration recommended as a threshold for a fish consumption advisory for the most sensitive human consumer group (0.2 mg Hg/kg for fetuses and developing children). Fish size is a very important factor determining Hg concentration. Thus, distribution of Hg and length data provide a better representation of the Hg data for the two

populations. The Orrington-Bucksport fish have higher concentrations of Hg relative to their size than the other white perch in the state. Multivariate analysis included individual fish length, lake location (whether it was selected by the deposition model or not), water color (as a surrogate measure for dissolved organic carbon), pH, mean depth, drainage area, flushing rate, distance from Holtrachem/PERC, and direction from HoltraChem/PERC (ranked as percent frequency of wind direction). Simple regressions were performed on each variable to the log of the Hg concentration in the fish. The highest correlation coefficients (r-values) were with log of the fish length (0.59), lake location (0.43), and direction (0.41). Because the model uses prevailing wind data as an important factor in lake selection, lake location and direction from the source are intercorrelated. Direction was not used in later multiple regressions. Stepwise multiple regression selected (in order of their contribution) log of fish length, lake location, drainage area, pH, color, and mean depth. The r-value was 0.80. Size and age of fish are positively correlated to Hg concentration. Drainage area, pH, water color (dissolved organic carbon), and mean depth (which also relates to temperature) are also known to be involved with delivery of Hg to a lake or in the methylation process that makes the Hg biologically available. For this study, lake location (those lakes selected by the deposition model to be most affected by atmospheric emissions from the Holtrachem facility) appears to also be a very important variable to describe the Hg concentration in the fish samples. Our hypotheses for local Hg deposition in Maine. Concentrations of Hg in fish, and lake and peat sediments in Maine are high, compared to the rest of the United States. Some of the higher concentrations in fish occur in eastern Maine, near several industrial activities, including the HoltraChem chlor-alkali chemical plant and the PERC waste incinerator, both in Orrington, and the Champion International Paper Company in Bucksport. A recent Department of Environmental Protection (DEP) report (Courtemanch et al., 1997) found that Hg concentrations in fish and surface sediment were significantly higher downwind of these sources compared to upwind. These findings suggest that the local sources may contribute significantly to the local Hg atmospheric emissions, measured against the regional Hg background deposition. We propose the following hypotheses: 1. Local sources of Hg emissions contribute significantly to atmospheric deposition of Hg (both wet and dry) on a local scale. 2. Atmospheric deposition rates of Hg from a point source is inversely related to distance from that source and directly related to the prevailing wind direction. 3. The response of lake biota and the sediment record to changes in atmospheric deposition of Hg is inversely related to the (watershed/lake) area ratio. Our research will test these hypotheses by determining the chemistry of dated sediment cores from lakes and bogs at varying distances from, and compass directions around, these Hg sources. We will determine the relative contributions of the local sources versus the regional background and the timing of changes in comparison to the onset and changes of local emission sources. The results of this work will be one of the first applications of paleolimnology to track effects from a small atmospheric point source of Hg and to verify the output of depositional models. Workplan. We will collect single sediment cores from the deep area of each of 8 lakes near Orrington, Maine. For these lakes, we already have data on Hg in fish and surface sediments that show that Hg concentrations are higher near and downwind of the local Hg sources (DEP, 1996). Two cores will be from a) a lake further downwind to determine how far the signal from the local sources is (or is not) measurable, and b) a lake significantly upwind of the sources to establish the regional baseline resulting from the continental Hg signal from the atmosphere. Cores will also be collected from at least two peat bogs where the influence of a canopy on dry deposition of Hg is effectively zero. It is essential that all these cores be dated by 210Pb (Norton et al., 1997; Binford et al., 1994) so that the chronology of Hg stratigraphy can be correlated with the emission history of the industrial sources. Total Hg concentrations will be determined from intervals of sediment. Fluxes of Hg to the coring site (mg Hg/cm2/yr) will be calculated based on the sediment chronology, mass accumulation rates, and concentrations of Hg. These fluxes will then be compared to the emission history for the local area, region, and continent. Methods We will collect single sediment cores from the deep area of each of 8 lakes near Orrington, Maine. For these lakes, we already have data on Hg in fish and surface sediments that show that Hg concentrations are higher near and downwind of the local Hg

sources (DEP, 1996). Two cores will be from a) a lake further downwind to determine how far the signal from the local sources is (or is not) measurable, and b) a lake significantly upwind of the sources to establish the regional baseline resulting from the continental Hg signal from the atmosphere. Cores will also be collected from at least two peat bogs where the influence of a canopy on dry deposition of Hg is effectively zero. It is essential that all these cores be dated by 210Pb (Norton et al., 1997; Binford et al., 1994) so that the chronology of Hg stratigraphy can be correlated with the emission history of the industrial sources. Total Hg concentrations will be determined from intervals of sediment. Fluxes of Hg to the coring site (mg Hg/cm2/yr) will be calculated based on the sediment chronology, mass accumulation rates, and concentrations of Hg. These fluxes will then be compared to the emission history for the local area, region, and continent.

Principal Findings and Significance

Early in the project, we recognized the possibility of establishing a gamma spectrometry laboratory for the purpose of conducting the radionuclide analyses proposed in the original grant proposal. With supplementary funding provided by the Office of the Vice Provost for Research at the University of Maine, in combination with rearranged budgeting for the 210Pb analyses (approved by the U. S. Geological Survey), we have established a functioning gamma laboratory providing the services needed in support of this research. 210Pb dating has been completed on 3 of 10 cores (see Table 1, below) and is underway on a fourth. All tasks of the project are well underway. We expect to complete tasks on the schedule indicated in Table 1. Site Coring Water concentration Loss-on-ignition 210Pb Hg concentration Caribou Bog Done Done Done Done Done Eddington Bog Done Done Done Done Done Brewer Lake Done Done Done 9/99 9/99 Jacob Buck's Pond 9/99 10/99 10/99 11/99 11/99 Long Pond Done 8/99 9/99 10/99 9/99 Swetts Pond Done Done Done Done Done Thurston Pond Done Done 10/99 8/99 Williams Pond Done Done Done 9/99 Done To be selected 10/99 11/99 11/99 12/99 11/99 To be selected 10/99 11/99 11/99 12/99 12/99 Table 1: Status of tasks on the project, as of August 1, 1999, with estimated date of completion Data analysis will occupy the first 2 to 3 months of 2000. Re-analysis of any samples, suggested by data analysis, will occur in mid-Spring. A final report and manuscripts will be prepared during the summer of 2000. Field work has been conducted by Professor Stephen Norton (PI), Amy Benoit (Undergraduate Student in charge of the two bog cores), John Cangelosi (Technician), Ewan Whitaker (Graduate Student), and Ethan Perry (undergraduate Student). 210Pb laboratory work has been conducted under the supervision of Professor C. Tom Hess by Amy Benoit and Mary-Jo Norris (Graduate Student). Chemical laboratory work has been supervised by Norton and Michael Handley (Laboratory Manager), and conducted by Cangelosi and Perry.

Descriptors

Mercury, incinerators, chlor-alkali, paleolimnology, atmospheric emissions, atmospheric deposition, bog sediment

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Benoit, Amy, 1999. A history of atmospheric mercury deposition derived from an ombrotrophic peat bog in Maine: Evidence for a local industrial source? Unpub. Honors Thesis, University of Maine, 28 p. plus Appendices.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Association of Methylmercury with Dissolved Organic Carbon: Implications for Bioaccumulation in Maine Freshwater Fish
Project Number	
Start Date	09/01/1998
End Date	08/31/2000
Research Category	Water Quality
Focus Category #1	Hydrogeochemistry
Focus Category #2	Toxic Substances
Focus Category #3	Water Quality
Lead Institution	University of Maine

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Aria Amirbahman	Assistant Professor	University of Maine	01
Terry A. Haines	Professor	University of Maine	02

Problem and Research Objectives

Statement of Critical Regional Problems: High concentrations of mercury (>0.5 mg/g wet weight) have been found in many species of freshwater fish in waters unaffected by direct discharge throughout the US. More fish consumption advisories resulting from mercury have been issued by state health agencies than for all other contaminants combined. This problem is especially acute in New England generally, and in Maine specifically. The Maine Department of Human Services Bureau of Health has issued a blanket fish consumption advisory because of mercury for all fresh waters in the state. This reduces recreational opportunity and eliminates a source of high quality protein for residents. These high

mercury concentrations also pose a threat to fish-eating birds and mammals. The source of the mercury is believed to be atmospheric deposition, but the mercury concentrations in biota are not uniform from water to water. Rather, mercury contamination of biota is highly variable and it is common for a lake containing fish with high mercury concentration to be located within a few hundred meters of another lake with relatively low fish mercury levels. In order to better target fish consumption advisories and to identify lakes where mercury contamination of biota is most likely to occur, a better understanding of the environmental factors that control the bioavailability of methyl mercury is needed. Statement of Results and Benefits: The role of dissolved organic carbon (DOC) in the bioavailability of mercury (and other trace metals) is complex. Studies of the role of water chemistry in fish mercury concentration nearly always identify DOC as an important variable, but have produced conflicting results concerning the nature of the interaction. The mercury burden in higher organisms consists almost entirely of monomethyl mercury (CH3Hg), and uptake is almost entirely through the diet, with a biomagnification factor of about 10 between trophic levels. However, uptake of CH3Hg from water into the bottom of the food chain (e.g., algae) has a bioconcentration factor of ca. 105. Dissolved organic carbon is most likely to affect the supply or bioavailability of MeHg to algae rather than transfer through the food chain to fish. This proposed research focuses on the characterization of natural DOC in Maine lakes and the interaction between DOC and CH3Hg as it relates to bioavailability of CH3Hg to algae. Through this approach we hope to identify key parameters that control CH3Hg bioavailability, and thereby improve our ability to identify classes of surface waters that are likely to have either high or low CH3Hg bioavailability. Our findings may be useful in improving the ability to predict CH3Hg concentration in fish, permitting the refinement of fish consumption advisories to exempt lakes where CH3Hg is unlikely to bioaccumulate, thereby increasing recreational fishing opportunities.

Methodology

Nature, Scope and Objectives of the Research: In freshwater systems, a strong correlation has been found between the aqueous concentration of different mercury species and DOC. However, DOC may be positively, negatively, or unrelated to fish mercury concentration, which consists virtually entirely of CH3Hg. Of particular interest is the interaction of CH3Hg and DOC in freshwaters, due to its bioaccumulation and toxic effect on higher organisms. It has been proposed that some forms of DOC bind CH3Hg very strongly and compete with living cells for available CH3Hg. Alternatively, some forms of DOC bind CH3Hg less strongly and may serve to move CH3Hg from sediment reservoirs into the water column, making it more available for uptake by organisms. Methylmercury concentration has been determined in fish species from about 150 lakes and reservoirs in Maine. We will use these data to select a group of lakes that span a wide range of CH3Hg and DOC concentrations. Laboratory studies will be designed to simulate the field conditions so far as the solution chemistry, nature and concentration of DOC and types of organisms are concerned. These studies will be devised to give us insight into the conditions that enhance the uptake of CH3Hg by the lacustrine organisms. This proposed research aims at elucidating the role of DOC in the bioaccumulation of CH3Hg in lacustrine organisms. We expect that the findings of this study will enhance our ability to predict CH3Hg concentrations in freshwater fish. The objectives of this study are as follows: 1) To examine the association of CH3Hg with the DOC from several lakes in Maine. The DOC from the selected lakes will be collected and their DOC will be concentrated. For one or more of the samples, the DOC will be fractionated based on physicochemical behavior. Acid-base properties and the elemental composition of the DOC will be characterized. Partitioning experiments using membrane dialysis technique will then be conducted to determine the relevant thermodynamic parameters for the stability of CH3Hg-DOC complexes, with the use of chemical equilibrium modeling. The stability constants obtained from these experiments will be correlated to the rate of uptake of CH3Hg by the organisms obtained by the following set of proposed experiments. 2) To study the effect of DOC on CH3Hg uptake by a

planktonic alga. Planktonic algae form the base of lacustrine food chains leading to fish. Algal cultures in the absence and the presence of varying concentrations of DOC isolated from the lakes will be amended with CH3Hg. The kinetics of uptake of CH3Hg by the organisms will be determined for different DOC samples and at varying solution chemistries and CH3Hg concentrations. It is expected that the rate of uptake of CH3Hg by the organisms will be inversely proportional to the stability of CH3Hg-DOC complexes as determined above.

Principal Findings and Significance

Complexation Studies The purpose of the proposed complexation studies is to develop the energetics of interaction between several species of dissolved organic carbon (DOC) and methylmercury (CH3Hg). We have accomplished the following tasks: Design of the experimental setup and analysis of methylmercury: Interaction between CH3Hg and DOC is studied using membrane dialysis. We have designed a set of glass reaction vessels for the dialysis experiments. A 500 Da membrane separates the two reaction vessels, one containing CH3Hg and the other the DOC solution. The free CH3Hg diffuses across the membrane only. We have successfully finished the base experiments to establish mass balance by determining the diffusion kinetics across the membrane, adsorption of CH3Hg to the membrane, efficient mixing scheme and minimizing loss due to evaporation. Methylmercury recovery in our system is usually above 90%. As part of the optimization process to prevent diffusion of DOC across the membrane, a maximum background ionic strength of 1mM has been established. We analyze CH3Hg using EPA's Method 1631. To obtain more reproducible data, we have optimized the oxidation of the organic matter prior to CH3Hg measurements by using UV oxidation followed by the addition of BrCl. This procedure has resulted in high recoveries of CH3Hg as well as high reproducibility of the complexation data. We have also tested different inorganic and organic pH buffers and selected those that do not interfere with the oxidation process. Experimental Results: At this stage, we have finished the experimental design and process optimization. A model DOC sample, well characterized peat humic acid (PHA) supplied by the International Humic Substances Society, has been used to determine the conditional stability constants. Adsorption isotherms for CH3Hg-PHA system have been obtained. A typical isotherm developed using 1 ppm of PHA is shown in next page. The behavior of this system is characterized by a very high affinity between CH3Hg and PHA. We have used a two-site Scatchard model that fits the data very well, as shown in the plot. The results show especially high affinity between the strong binding sites and CH3Hg. X-ray spectroscopic data estimate that concentration of the reduced sulfur functional groups in humic substances range between 30 to 200 nmol / mg-HA. The site capacities obtained in this study indicate that only a small fraction of the reduced sulfur groups on PHA are occupied. Concentration of total CH3Hg in natural waters is usually in the picomolar (10-12 M) range. Our observations demonstrate that DOC can indeed control the speciation of CH3Hg in the aquatic environments. Future planned work includes developing similar isotherms at different pH values for two other well-characterized humic substances and two water samples from lakes in Maine with relatively high DOC concentrations. Also complexation of CH3Hg will be studied at different concentrations of lake water samples. Algal Studies A culture of the planktonic green alga Selenastrum capricornutum was obtained from the University of Texas and grown in standard media in the laboratory. An initial culture was contaminated with another alga species, which was traced to filters in the laboratory water treatment system. The filters were replaced and a new culture obtained, without problems. Agitation of the cultures with room air supplied by standard aquarium pumps was found to result in significant mercury contamination. Cultures are now agitated with mercury-free nitrogen gas, and mercury content of the algae is nominal. We are now ready to begin exposure of algae to methylmercury with and without dissolved organic carbon. We anticipate that such exposures will begin the week of August 9.

Descriptors

Dissolved organic carbon, organometallic compounds, contaminant transport, fish ecology, lakes

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

A Masters Disseration/Thesis is planned to be completed by 12/99.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Reid, A., Amirbahman, A. and Haines, T., 1999. Association of methylmercury with dissolved humic acids. Poster presentation: 1999 Maine Water Conference, Augusta, Maine. Reid, A., Amirbahman, A. and Haines T., 1999. Complexation of methylmercury by peat humic acid. Poster presentation: Association of Environmental Engineering and Science Professors, Research Frontiers Conference, University Park, PA.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Using Semi-Permeable Membrane Devices for Detecting and Assessing Risks of Exposure to Dioxins in Natural Waters
Project Number	
Start Date	09/01/1998
End Date	08/31/2000
Research Category	Water Quality
Focus Category #1	Waste Water
Focus Category #2	Toxic Substances
Focus Category #3	Solute Transport
Lead Institution	University of Maine

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Howard H. Patterson	Professor	University of Maine	01
Touradj Solouki	Assistant Professor	University of Maine	02
Therese D. Anderson	Professional Staff	University of Maine	03

Problem and Research Objectives

Abstract Polychlorinated dibenzo-p-dioxins (PCDD) and dibenzo-p-furans (PCDF) are ubiquitous in the global environment and are introduced from a variety of natural and anthropogenic sources and processes. Because of their well-documented carcinogenic and reproductively toxic characteristics, PCDD/F emissions and bioaccumulation are the subject of intense public health debate and research. Maine has one of the most intensive toxic screening programs underway in the country for metals, PCBs, dioxins/furans, and pesticides in rivers, streams, and lakes. The Surface Water Ambient Toxics (SWAT) program is intended to help environmental managers and policy makers resolve problems regarding toxic contamination based on statewide analysis of the distribution and severity of toxic contamination in surface waters. The various Kraft mills in Maine have worked with the Department of Environmental Protection (DEP) on the Governor's "upstream-downstream" Proposal; under this document, levels of dioxin in Maine rivers below a Kraft mill must not exceed the levels above that mill. Finding an accurate way to routinely monitor dioxin levels will help to implement this plan. The goal is to replace the existing methods of destructive sampling of organisms with semipermeable membrane devices (SPMDs) as a uniform sampling method. The SPMDs mimic biological systems and concentrate trace organic contaminants from aqueous solutions, thus providing a cost-effective and convenient measure of bio-available pollutants in any specific site (Huckins, Tubergen et al. 1990). The general experimental design can be broken up into the two field seasons of 1999 and 2000 and are as follows: These field studies are carried out in collaboration with the state of Maine DEP. In the 1999 Field Season, SPMDs are being placed above and below a Kraft paper mill on the Penobscot River in Maine. Fish at these same sites collected by DEP personnel will be analyzed for dioxin and the data compared with the SPMDs' dioxin analysis. In Field Season 2000, using the results from 1999, six sites along the Androscoggin River will be monitored to determine the variations in dioxin concentrations. Several of these sites can not be effectively monitored by current DEP methods. The results of this project will determine the effectiveness of SPMDs under a range of environmental conditions to determine whether and when the devices are suitable as indicators of dioxin exposure. This indicator method will be useful for a host of purposes, including such important goals as 'upstream-downstream' dioxin source testing. Nature of the Problem Investigated Goal: To monitor the amounts of dioxins/furans in a waterway. Old Method of Assessment: Destructive Sampling of Fish Due to the bio-accumulating nature of dioxins, fish are used for analysis because these dioxins not only accumulate through the gill epithelium during direct dermal contact and respiration but also through the ingestion of dioxin-containing materials (Huckins et al. 1996). The collected fish are ground and blended and dioxins/furans are extracted and analyzed using EPA Method 1613B. The problems that this method presents were systematically described in our proposal and include the facts that fish populations are non-uniformly distributed, it is impossible to have a truly homogeneous sample for extraction and analysis, older fish are more contaminated, fish metabolize dioxin slowly, and the fish population depletes because of the large sampling needed for analysis. Another disadvantage presented with this method is that it provides concentrations for bioaccumulation, which encompasses all forms of an organism's dioxin intake, and not bioconcentration. Bioconcentration is merely the concentration of the dioxin directly from the surrounding water into the lipids of an organism (Huckins et al. 1996). Therefore, in assessing the

'upstream-downstream' proposal ramifications, it is essential to develop a method which is both reliable in its sampling of a particular location, a weak point with the fish due to their mobility, and which involves exposure of the sample for a fixed deployment time that is uniform for both upstream and downstream testing sites. New Method of Assessment: Semipermeable Membrane Devices (SPMDs) An SPMD consists of a thin film (1 mL, 0.915 g) of triolein, which is a large-molecular-weight neutral lipid found in fish, encased by a low density polyethylene membrane measuring 91.4 cm in length and 2.5-cm wide (McCarthy and Gale. 1999). This configuration allows the SPMDs to mimic biological systems, the fish in our study, and concentrate trace organic contaminants from aqueous solutions, thus providing both a cost-effective and a convenient measure of the bio-available pollutants in any specific site (Huckins, Tubergen et al. 1990). Moreover, SPMDs lack both the mobility and homogeneity problems presented with the fish. However, while the use of SPMDs solves these problems, it presents some of its own. The affects of biofouling, temperature, and DOC on SPMD sampling rate lead to the need to assess these factors at each site and to strive for uniformity of these parameters among all of the sites during each deployment period.

Methodology

Experimental Methods The focus of our field studies thus far has been to select comparable sites along the Penobscot River around a Kraft paper mill in order to determine the effectiveness of the semipermeable membrane devices (SPMDs) in accumulating dioxins and furans during a 28 day deployment period. The importance of comparable environmental conditions is best expounded in Huckins et al, 1996. There, the investigators stress that the mass of an analyte sequestered by an SPMD depends on the parameters of the temperature of the water, the water concentration of the analyte of interest (in our study, dioxins and furans), and the extent of SPMD biofouling. Sites were deemed comparable during deployment site determination when all of the site temperatures measured within + 2oC of one another. Onset temperature loggers were purchased and placed on selected SPMD canisters in order to monitor the temperatures every hour during deployment. The advantages of these data loggers are best illustrated by their outputs from the first deployment (Figures 1a-c). They offered a confirmation that the site temperatures remained within the 4oC spread of each other throughout the water exposure period, which is vital since sampling rate is temperature-dependent (Huckins et al.1996). The water concentration at a particular site is affected by such parameters as the amount of organic carbon and total suspended solids in the river at that site (McCarthy and Gale. 1999). Therefore, we have collected water samples at both deployment and retrieval in order to compare these parameters between all sites chosen during a deployment. This water quality data is provided in Table 1. Heather Shoven measured the water quality parameters with the help of the Water Research Institute staff. She has been taught all of these procedures by the staff and in exchange for the work spent on her samples by the staff, she performs these tests on samples for the Water Research Institute. Biofouling is characterized as periphytic growth on the membrane surface, which occurs after a period of exposure to the river elements. It has been found to lead to slowing of the SPMD sampling rate because biofouling of the membrane diminishes its available surface area (Gale et al. 1997). Biofouling potential of an SPMD is best investigated through water quality testing of a suite of characteristics at each site: these include measuring apparent color, chlorophyll a, total phosphorus and turbidity. Through these figures, also supplied in Table 1, a picture of site comparability can be realized. Specific conductance was included as one of the parameters tested on collected water samples because it provides a good indication of whether or not the sites are in the path of wastewater plume (Polak and Palmer. 1977). The aim of this project is to be able to use SPMDs in the future to monitor compliance of the paper mills to the upstream-downstream regulations. Therefore, the method of specific conductance is used to be assured that the discharge from the mill is being sampled as a possible source for introduction of dioxins/furans into the river. Sites and Field Apparatus The vertical deployment apparatus for SPMDs

designed by Barry Poulton and Brad Mueller was unable to be used because of its inclusion of steel rebar in its specifications. To avoid the use of rebar on the Penobscot, an alternative design was developed by Water Research Institute Field Coordinator Richard Dill, along with Heather Shoven, and it is presented in Figure 2. This collection of anchors and buoys not only allowed for a vertical deployment, but also placed the canister at a fixed depth below the surface (three feet below for the first deployment and two feet below for the second deployment). It is important for the SPMD canister to not touch the riverbed. Riverbed constituents have a tendency to sequester dioxin; therefore, during our deployments, the canister remains free of the riverbed so as to sample only the constituents in the water. All of the sites from the first two deployments are located on Figure 3 and are numbered accordingly. The first deployment included three sites around a Kraft paper mill which are illustrated in Figure 4. Each SPMD site had one canister and each canister held three-separate SPMDs. Initially, we were hoping to analyze each SPMD in the canister separately, thus providing us with triplicates at each site. However, initial analysis has demonstrated that this tactic is not feasible on the Penobscot River; therefore, the three SPMDs at each site will now be combined to create one sample for each canister. As can be seen in Figures 3 and 4, Site-1 was located just upstream of the town's sanitary district outlet. This was done in order for us to determine a background concentration of the possible dioxins/furans entering the area under investigation. Site-2 was placed just upstream of the Kraft mill wastewater outlets in order to monitor the discharge from the sanitary district. Finally, Site-3 was located 200 feet below the Kraft mill wastewater outlets. These SPMDs have been processed through use of proprietary Standard Operating Procedures provided by EST laboratories and are in the HR GC/MS analysis stage. While concrete data is pending, initial runs of some of the samples have shown promise that bioconcentration did occur. The second deployment period, July 21 to August 18, included sites 3, 4, and 5, which are all shown in Figure 3. All downstream sites were chosen because our main focus at this point is to see how these SPMDs concentrate dioxins/furans at different sites and distances from the possible point source. Two canisters were placed at site three because we are interested in testing the precision of the devices. Deployment three will most likely include four sites with our focus shifting to the differences in concentrations along two transects of the river. We ultimately want to determine through these field procedures: how much mixing of the plume occurs and where should we place the SPMDs in possible future upstream-downstream scenarios? Quality Control During the first deployment and retrieval one trip blank was exposed to the atmosphere during the entire atmosphere exposure period of each SPMD before the canister's submersion into the river. This was done to assess the amount of dioxins/furans sampled in the air since these devices are excellent passive air samplers as well (Petty et al. 1993). The values obtained for the trip blanks will be used to confirm the possible amounts of dioxins/furans sampled in the air by the deployed SPMDs. For laboratory quality control of the extraction procedure, three controls were run through the standard operating procedures for extraction and cleanup along with the deployed samples and trip blank. These controls included: (1) a process blank to determine the possible background concentrations in the solvents, glassware and equipment used in the procedures, (2) a dialysis blank to determine the background in a fresh SPMD, and (3) a matrix spike to determine the efficiency of the sample preparation and analysis. All SPMDs were spiked with surrogates so that surrogate recovery could be used to correct for the overall dioxin/furan concentrations (Telliard. 1994).

Principal Findings and Significance

Plans for the Remainder of the 1999 Field Season and Beyond · Complete a total of four SPMD deployments (thus two more, September and October Retrievals) for a total of 15 canisters sampled in the Penobscot River. · Compare data gleaned from HR GC/MS analysis of the SPMD contents with the 1999 fish collected in the Penobscot River by the SWAT program. · Determine methods for accurately quantifying the SPMD data for dioxins and furans. Research to probe deeper into the environmental

effects on the sampling rates of the SPMDs. · Develop plans for Part II of this project: Field Season 2000 on the Androscoggin River, this includes the evaluation of our current protocols for site selection.

Descriptors

Pollution control, pollutants, contaminant transport, membranes, organic compounds, model studies

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Heather Shoven, Graduate Rsearch Assistant in EES Master Program is expected to complete a Masters Dissertation in May 2001.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Information Transfer Program

A major goal of the Water Research Institute is to foster increased cooperation and communication between the academic community, state agencies, environmental organizations, and private companies. Using portions of staff time and substantial non-USGS funding, the WRI has maintained an active program of dissemination of research results, conferences and meetings, service on committees dealing with water resource issues, working with teachers and conducting special projects. The main Information Transfer project separately funded during the regional competition was PEARL (Public Educational Access to Resources on Lakes), the Maine lakes database. It is listed under research because of the mechanism of funding. Other Information Transfer activities in 1998 are described below: Conferences and Workshops The WRI is the lead organization in organizing and conducting the annual Maine Water Conference. This conference in Augusta provided expanded technical sessions, in addition to the issues orientation that has been part of previous MWCs. The conference now consists each year of a morning plenary session, 4 to 6 afternoon concurrent sessions, and in 1999 will expand to include a field trip. Water Resources Education The WRI administers Project WET (Water Education for Teachers) in Maine under a formal agreement signed with national WET in 1996. This program was new to the State of Maine in 1994, and continues to expand in scope. Instructional workshops for teachers are day-long, hands-on workshops for 20 to 25 teachers. Each teacher receives the hardbound WET curricula and activity guide covering over 90 activities, paid for by the WRI and outside donors. Testing the Waters - Discovering the Penobscot River Watershed. This educational program provided a hands-on, minds-on water quality monitoring and educational experience for more than 1,000 schoolchildren and teachers along the Penobscot River in Maine. Participants were encouraged to become active environmental stewards, gathering a snapshot of their community watershed by collecting water samples simultaneously at over 40 stations along the Penobscot River and its tributaries. Funding support for the 1998 TTW program was provided by U.S. EPA Environmental Education Grants Program, Maine Outdoor Heritage Grants Program, and Maine Project WET. The Institute received the 1999 Governor's Award for Environmental Excellence in acknowledgement of the TTW program. AmeriCorps SERVE/Maine - The Institute sponsored an

AmeriCorps Serve/Maine Volunteer Leader, Laura Wilson, during October 1977 to October 1998. The focal point of this AmeriCorps outreach experience included the expansion of local awareness of water quality issues at the Branch Pond watershed in Eastern Maine. Educational and outreach activities included: completion of the Branch Pond watershed survey, controlling eutrophication by reducing soil erosion in the watershed, expansion of volunteer lake monitoring, and increasing public awareness of nonpoint source pollution issues. This Americorp volunteer also worked with the Maine Volunteer Lake Monitoring Program to enlist several new lake volunteers in the downwast Maine region. The Water Research Institute is a partner with VLMP in lakes monitoring, and the WRI Director serves on the VLMP Board of Directors. Data Dissemination and Access The WRI developed a web page for the Maine Volunteer Lake Monitoring program in 1998. This augmented the PEARL web page, and provided the VLMP with its first web presence. Newsletter and Digests The WRI publishes its newsletter Waterlines on a irregular quarterly schedule. This newsletter contains information on ongoing and upcoming grants, developments in the WRI laboratory, news releases from the University on water resources related issues, and announcements for our conferences. Our regular contributors include the USGS in Augusta and other water resource professionals on campus and in Maine. In 1998, the WRI published an information digest on Maine's Wellhead Protection Program, in collaboration with the state Drinking Water Program. A report by the Resources Economics group at UMaine was commissioned by the WRI to support the activities of the Great Pond Task Force. The conclusions of the report were that Maine lakes are indirectly Maine's second largest employer (after forest products), and contribute more to the state economy that Bath Iron Works, the state's single largest employer. Committees and Commissions Graduate education. The Director of the Institute served on 13 graduate student committees in environmental science and water resources in 1998. Co-chair, Council on Environ. Monitoring and Assessment (Gubernatorial appointment). The Institute Director is the co-chair of CEMA, which was formed by executive order on Earth Day, 1998. CEMA will work to increase coordination among volunteers and agencies which collect environmental data. This work will include a web page and on-line database of monitoring activities in Maine. Maine Great Pond Task Force. The enabling legislation establishing the GPTF included several named members, including the director of the WRI. Since 1996, this activity has included monthly meetings of the entire task force, numerous meetings of the water quality subcommittee and the finance subcommittee, and several public hearings statewide. The WRI director has prepared two working papers for the task force as well. The WRI digest on Maine Lakes has been widely circulated in Maine as a result of the GPTF activities. Board of Directors, Maine Volunteer Lake Monitoring Program. The WRI Director is a member of the board of the Maine Volunteer Lake Monitoring Program. The WRI has had a long standing involvement with the VMP, including technical and analytical contributions. The Penobscot Institute is the host organization for Penobscot Riverkeepers 2000, described above in the general public service section. Corporate Affiliate Program. The University of Maine CAP involves more than 40 companies in a cooperative program to foster collaboration and information exchange between the University and business. The CAP involves workshops and meetings among the various partners and the University. Scientific Advisory Panel, Maine Forest Biodiversity Project. The Institute is serving as a scientific advisor on watershed issues for the FBP, an interagency/private sector task force to define, among other things, how to set up a natural areas reserve system in Maine. River Flow Management Commission. (Gubernatorial appointment). The RFAC is an advisory group comprised largely of state agency representatives which deals with stream flow and storm flow, especially in the context of potential spring flooding. A statewide snow-survey is conducted each spring by the Commission. Maine Forest Advisory Team. This interagency/industry/environmental advisory group was established to evaluate forest practices and BMPs, to define compliance and set compliance goals, and to refine BMPs and guidelines for other forest practices.

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	3	N/A	10	15
Masters	1	5	N/A	13	19
Ph.D.	1	N/A	N/A	1	2
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	4	8	N/A	24	36

Awards & Achievements

Research Achievements The Maine Institute serves on the New England Governors/Eastern Canadian Premiers working group on acid rain, which is helping guide the present debate and influence possible lawsuits involving EPA and air emissions from mid-western states. Maine Institute research was the centerpiece of a 1998 report to the EPA OAR acid rain division on the impacts and trends on surface waters in Maine. This report was funded by OAR as they prepare to report to Congress on the effectiveness of the 1990 Clean Air Amendments. Related to the Clean Air Act, the Maine Institute, via IAG through the WRRI, has assumed responsibility for the 1999-2003 EPA acid rain monitoring program in the northeastern US (Adirondacks to Maine). USGS-funded research in Maine (by a geologist and a historian) established that arsenic in groundwater was as likely to be from anthropogenic uses as from bedrock sources. This concept was a change from conventional wisdom in northern New England, and the idea has slowly been accepted and investigated by state agencies and NAQWA as we continue to investigate the issue. Acid rain research based in the Maine WRI was published as an entire special issue of Environmental Monitoring and Assessment in March: The Bear Brook Watershed in Maine: A paired watershed experiment--the first decade, 1987-1997. Information transfer and Public Service The Director served on the Maine Great Ponds Task Force from 1996 to 1998, as a result of which the Institute published a report to the legislature entitled 'The Impact of Lakes on Maine's economy' (conclusion: state's second largest 'employer'). This report was a centerpiece of the Task Force recommendations to the legislature, and helped pass legislation re-establishing the Lakes Division (at 500K/yr) in the Maine DEP in 1998 after the legislature had abolished it in 1991. Several pieces of lake protection legislation were also passed in 1998. The Director testified to the legislature twice during the process. The current and former directors of the Maine Institute were lead-author and co-author of the 1998 draft Water Resource Management Plan for Acadia National Park, the first such document ever done for the park. It is a planning document intended to guide management and research at Acadia for the next decade. Awards The Maine Institute won the 1998 EPA New England Environmental Merit award for 'developing on the premier environmental chemistry programs in the nation'. The Maine Institute was awarded the Governor's award for Excellence in Environmental Education for implementing Testing the Waters via an EPA grant, a new outreach and educational program in Maine.

Publications from Prior Projects

Articles in Refereed Scientific Journals

Kahl, J., S. Norton, I. Fernandez, L. Rustad, and M. Handley. 1999. Nitrogen and sulfur input-output budgets in the experimental and reference watersheds, Bear Brook Watershed in Maine (BBWM). Environ. Monitoring and Assessment 55:113-131. David, M., G. Vance, and J. Kahl, 1999. Chemistry of dissolved organic carbon at Bear Brook Watershed, Maine: Stream water response to (NH4)2SO4 additions. Environ. Monitoring and Assessment 55: 149-163. Norton, S., J. Kahl and I. Fernandez, 1999. Altered soil-soil water interactions inferred from stream water chemistry at an artifically acidified watershed at Bear Brook Watershed, Maine USA. Environ. Monitoring and Assessment 55:97-111. Stoddard, J.L., J.S. Kahl (8th co-author), and 21 others, 1999. Recovery of lakes and streams from acidification: regional trends in North America and Europe. Nature, in press. Norton, S.A., J.S. Kahl, I.J. Fernandez, L.E. Rustad, T.A. Haines, S.C. Nodvin, J.P. Scofield, T.C. Strickland, P.J. Wigington, and J. Lee, 1999. The Bear Brook Watershed in Maine (BBWM). Envir. Monitoring and Assessment 55:7-51. Roy, S., S.A. Norton, I.J. Fernandez, and J.S. Kahl, 1999. Linkages of P and Al export at high discharge at the Bear Brook Watershed in Maine. Environ. Monitoring and Assessment 55:133-147. Stoddard, J.L. C.T. Driscoll, J.S. Kahl, and J. Kellogg, 1998. Can site-specific trends be extrapolated to the regional level? Ecological Applications, 8:288-299. Stoddard, J., C. Driscoll, J.S. Kahl, and J. Kellogg, 1998. A regional analysis of lake acidification trends for the northeastern US, 1982-94. Environ. Monit. and Assess. 51:399-413. Norton, S.A., Evans, G.C., and Kahl, J.S., 1997. Comparison of Hg and Pb fluxes to hummocks and hollows of ombrotrophic Big Heath bog and to nearby Sargent Mt. Pond, Maine, USA: Water, Air, and Soil Pollut. 100:271-286.

Book Chapters

Dissertations

Kahl, J.S., 1998. Controls on the geochemisty of headwater systems in Maine. Ph.D Dissertation, Dept. Geological Sciences, University of Maine, Orono, ME. 359 p.

Water Resources Research Institute Reports

Pinette, S., J.S. Kahl, and S. Hasbrouck, 1998. The wellhead protection program: Maine's passport to safe drinking water. Final report to the Department of Human Services; Water Research Institute Digest 98-1. 16 pages. Boyle, K, J. Schuetz, and J.S. Kahl, 1997. Great Ponds play an integral role in Maine's economy. Water Research Institute final report to Maine State Planning Office. 50p.

Conference Proceedings

Other Publications

Kahl, J.S. D. Manski, M. Flora, and N. Houtman, 1998. Draft Water Resources Management Plan, Acadia National Park. 89 p.