State of Washington Water Research Center Annual Technical Report FY 2001

Introduction

The mission of the State of Washington Water Research Center (SWWRC) is to:

i) facilitate, coordinate, conduct, and administer water-related research important to the State of Washington and the region,

ii) educate and train engineers, scientists, and other professionals through participation in research and outreach projects, and

iii) disseminate information on water-related issues through technical publications, newsletters, reports, sponsorship of seminars, workshops, conferences as well as other outreach and educational activities.

The SWWRC has developed a multi-pronged approach to accomplish these goals. To promote research and outreach, the SWWRC has been organized into five program areas: Watershed Management, Water Resources and Biotic Systems, Groundwater Systems, Irrigated Systems, and Outreach and Education. These programs have helped prepare several multidisciplinary research proposals and provide better links between faculty and the SWWRC. The Center is also involved in international research and education activities.

The SWWRC is continuing its intensive efforts to reach out to agencies, organizations, and faculty throughout the State. Activities include presentations to watershed groups, participation in regional water quality meetings, and personal contacts. A new dynamic web page has been created to share information with stakeholders.

It is within this overall context that the USGS-funded project activities reported in this document must be inserted. These include the internally funded projects as well as the national proposals awarded to the Center. These projects provide a solid core to the diverse efforts of the SWWRC. Water quantity and quality issues continue to be a major concern in the State of Washington due to the endangered species act, population growth, industrial requirements, and agricultural activities. Emerging issues such as arsenic removal at small systems, emergency response and vulnerability, and storm water runoff regulations are also beginning to raise concerns. All of these issues will be important drivers of the activities of the SWWRC in the foreseeable future.

Research Program

In accordance with its mission, the SWWRC facilitates, coordinates, conducts, and administers water-related research important to the State of Washington and the region. The Center supports competitively awarded internal grants involving water projects evaluated by the Joint Scientific Committee. The Center also actively seeks multidisciplinary research on the local and national levels. Meetings between stakeholder groups, potential funding agencies, and research faculty are arranged as opportunities arise. Faculty are apprized of any opportunities. The Center also submits proposals on its own behalf.

Integration of Surface Irrigation Techniques to Reduce Sediment and Nutrient Loading in the Yakima River Basin

Basic Information

Title:	Integration of Surface Irrigation Techniques to Reduce Sediment and Nutrient Loading in the Yakima River Basin
Project Number:	2000WA4G
Start Date:	9/1/2000
End Date:	8/31/2003
Funding Source:	104G
Congressional District:	Washington Fourth
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Sediments, Irrigation
Descriptors:	Grass lining, check dams, surface drains, tailwater, surge irrigation, PAM, polyacrylamide, Yakima River, salmon recovery, surface irrigation, nutrient loading, sediment loading, erosion, non-point pollution
Principal Investigators:	Brian G. Leib, Robert Stevens, Ariel Szogi

Publication

1. Leib, B.G., R. Stevens, and C. Redulla, 2002, Integration of Surface Irrigation Techniques to Reduce Sediment Loading in the Yakima River Basin of Washington, USA, "in" Proceedings, International Workshop on Conservation Agriculture for Wheat and Cotton Production in Limited Water Resource Areas, Tashkent, Uzbekistan, October 13-18, 2002.
2. Leib, B.G., R.G. Stevens, C.A. Redulla, G.R. Matthews, and D.A. Strausz, 2002, Integration of Surface Irrigation Techniques to Reduce Sediment and Nutrient Loading in the Yakima River Basin, "in" Proceedings, Agriculture and Water Quality in the Pacific Northwest, Yakima, Washingon, November 19-20, 2002, pp. 15.
3. Leib, B.G., and D.A. Strausz, 2002, Surface Irrigation Improvement Project (SIIP) Web Page, Washington State University Cooperative Extension, Pullman, Washington, http://siip.prosser.wsu.edu.

PROBLEM AND RESEARCH OBJECTIVES

Surface (rill) irrigation has been identified as one of the main sources of excess sediment in the Yakima River Basin. In turn, it is this source of water quality degradation that is thought to be one of the causes for declining salmon runs in the Yakima River. The Washington Department of Ecology has set a sediment limit for irrigation return flows of 25 NTUs (56 mg/l). Some irrigators are converting their rill irrigation systems to either sprinklers or drip irrigation at a cost of $300 to $1000 per acre. In some cases, this large capital investment in improved irrigation systems is being offset by cost share and low interest loan programs. However, there is not enough cost share money to match the rill acreage and many irrigators cannot afford to convert their irrigation systems even if cost share were available to everyone. Therefore, many rill irrigators are attempting to improve their existing systems in order to keep their operations as profitable as possible. Many rill irrigators are applying Polyacrylamide (PAM) and successfully decreasing sediment loads from furrows by 80 to 90 percent. Unfortunately, this cleaner water often erodes sediment from the tailwater ditch causing elevated NTU levels still too high to be returned to irrigation district canals and drainage ditches. The focus of this research is on inexpensive methods to further reduce sediment and nutrient loads from rill irrigation. Sediment loads are being evaluated for PAM ($20/ac per year) used with Surge irrigation ($125/ac), tailwater drains ($75/ac), tailwater checks ($25/ac), and grass-lined tail ditches ($25/ac).

METHODOLOGY

The five treatments are: Treatment 1 - PAM alone as the control; Treatment 2 - PAM and Surge irrigation; Treatment 3 - PAM and closely spaced surface drains in the tailwater ditch; Treatment 4 - PAM with a grass-lined tailwater ditch; and Treatment 5 - PAM and tailwater checks. The treatments were installed at two locations during the 2001 growing season and will be repeated during the 2002 growing season. Data was collected during five irrigation events in 2001 and the goal for each year was to monitor eight irrigation events, four at each site. The treatments were randomized at each site and the treatments were large enough to allow 24 and 16 furrows, respectively to flow into the tailwater ditch.

Each treatment was monitored for inflow, outflow, soil moisture, sediment load, nutrient concentration. Inflows were estimated by measuring the time needed to full a bucket of a known volume. Outflow from each treatment was measured by a flow meter that received water from a collection sump and sump pump. Soil moisture was monitored with the neutron probe and access tubes. Average advance time was also recorded. Sediment samples were collected at periodic intervals during irrigation runoff. These samples were analyzed with an NTU meter and gravimetrically with filter paper.

Composite samples were also collected from irrigation runoff events for nutrient analysis. Samples were taken as water fell into the tailwater sumps. Samples were kept at 4 degrees C until chemical analyses. All water quality analyses were performed using EPA methods (U.S. EPA, 1983). Soluble compounds were determined in samples filtered with a 0.45 µm pore-size membrane and analyzed for ammonium-nitrogen, nitrate-nitrogen, and soluble reactive phosphorus. Unfiltered samples were analyzed for total Kjeldahl nitrogen, and total phosphorus.

After outflow was measured, the tailwater effluent was delivered to a sediment trapping boxes consisting of slotted apple crates lined with filter fabric to retain sediment. The number of boxes was dependant on the expected tailwater flow. The depth of sediment added to the boxes was measured at the end of the irrigation season.

PAM was applied to all the furrows just below the point of water delivery and at the time when the furrow soil had been disturbed by field operations. Similarly, all other cultural practices such as weed control and fertilization was held constant between treatments according to standard production practices.

PRINCIPAL FINDINGS AND SIGNIFICANCE

- Formed a project management/oversight team comprised of members from a cross section of Tribal Offices and Government Agencies.
- Gary Matthews, Engineering Technician, was retained to fabricate, install and maintain the monitoring equipment needed for this experiment.
- Two "on-farm" experiments/demonstrations were installed on cooperating farms. Colin Mears and Billy Korstad in the Wapato Irrigation District cooperated on a 40-acre, rill irrigated, grain corn field with 1300 foot runs and a 0.2% slope on the tailwater ditch. Ken Lewis of the Roza Irrigation District cooperated on a 30-acre, rill irrigated, Concord grape field with 800 foot runs and a 1.2% slope on the tail water ditch. Five data collection runs were completed on these fields during the 2001 growing season. The results of these experiments are still being analyzed. However, total sediment, runoff volume, and average sediment concentration for each site and event are shown in Tables 1, 2 and 3, respectively.
- Information Transfer Activities: 1) Project Coordination & Planning Meeting, October 27, 2000, attended by WSU Extension, Yakama Tribal Representatives, BIA, NRCS, and USGS; 2) Project Coordination and Planning Meeting, January 31, 2001, attended by WSU Extension, Yakama Tribal Representatives, BIA, NRCS, USGS, EPA, and cooperating producer; 3) Informational Meeting for Yakama Tribe Members and agricultural lessees, April 25, 2001, 50 participants; 4) Field Tour of the Concord Grape Demonstration Site by group of visiting scientist from Uzbekistan, August 18, 2001, 8 participants; and 5) Field Tour of the Concord Grape Demonstration site by local irrigators and community members, September 8, 2001.

Table 1. Amount of sediments (g) in runoff water at several irrigation events in 2001.

Treatment	Site				
	Lewis Vineyard			Mears Cornfield	
	June 12-14	July 22-24	Aug 13-15	July 16-18	July 28-30
Grass	1828	462	1408	4946	3964
Check	3180	2554	14301	39201	6318
Surge	3358	2967	155205	24817	7728
Subsurface drain	6925	2498	54664	4356	4750
Control	67778	64267	330902	31059	7144

Table 2. Total volume of runoff water (x 10gal) at several irrigation events in 2001.

Treatment	Site				
	Lewis Vineyard			Mears Cornfield	
	June 12-14	July 22-24	Aug 13-15	July 16-18	July 28-30
Grass	1135	1175	1797	3857	5906
Check	852	1137	2518	7868	4239
Surge	530	1005	1799	3825	3544
Subsurface drain	1237	1259	2289	1571	3358
Control	1184	2953	3131	6459	4179

Table 3. Average concentration of suspended solids (mg/L) in the runoff water at several irrigation events in 2001.

Treatment	Site				
	Lewis Vineyard			Mears Cornfield	
	June 12-14	July 22-24	Aug 13-15	July 16-18	July 28-30
Grass	38	10	24	24	24
Check	164	46	201	256	37
Surge	193	70	1875	210	68
Subsurface drain	185	55	671	49	46
Control	1389	613	3279	181	56

Surface and Subsurface Transport Pathways of Non-Point Agricultural Pollutants: Analysis of the Problem over Four Decades of Basin Scale

Basic Information

Title:	Surface and Subsurface Transport Pathways of Non-Point Agricultural Pollutants: Analysis of the Problem over Four Decades of Basin Scale
Project Number:	1999WA0013G
Start Date:	9/1/1999
End Date:	9/30/2002
Funding Source:	104B
Congressional District:	5th
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Nitrate Contamination, Groundwater
Descriptors:	Agriculture, Contaminant Transport, Fertilizers, Groundwater Hydrology, Groundwater Quality, Herbicides, Isotopes, Leaching, Nitrogen, Nutrients, Organic Compounds, Pollutants, Rivers, Runoff, Solute Transport, Unsaturated Flow, Water Quality
Principal Investigators:	Richelle Allen-King, C. Kent Keller

Publication

1. Lemond, Luke, 2002, Silica Budgets of the Lower Columbia and Lower Snake Rivers, "Undergraduate Honors Thesis", Department of Geology, Washington State University, Pullman, Washington, 37 pp.
2. Allen-King, R.M., C.K. Keller, J.L. Smith, T. Van Biersel, and J. Schaumloffel, 2001, Field Scale Pesticide Transport To Ground and Surface Water, "in" Proceedings, V.M. Goldschmidt Conference, Hot Springs, Virginia.
3. Van Biersel, T.P., R.M. Allen-King, C.K.Keller, and J.L. Smith, 2001, Ground and Surface Water Contribution to Chemical Mass Discharge in a Semi Arid Dryland Agricultural Watershed, "in" Abstracts with Programs, Geological Society of America, Boston, Massachusetts, 33(6), abstract no. 28903.
4. Simmons, A.N., R.M. Allen-King, T.P. Van Biersel, C.K. Keller, J.L. Smith, 2001, Using Chemical Tracers To Estimate Pesticide Mass Discharge in an Agricultural Watershed, "in" EOS Trans. AGU,

82(47), Fall Meeting Suppl., Abstract H32B-0312.

5. Simmons, A.N., R.M. Allen-King, T.P. Van Biersel, C.K. Keller, and J.L. Smith, 2002, Ground and Surface Water Contribution to Chemical Mass Discharge in a Semi Arid Dryland Agricultural Watershed, "in" Proceedings, 2002 Research and Extension Regional Water Quality Conference, February 20-21, 2002, Vancouver, Washington, 3 pp.
6. Allen-King, R.M., C.K. Keller, J.L. Smith, T.P. Van Biersel, M. Flury, and M.E. Barber, 2001, Water Quality from Field to Basin Scales, Invited Presentation at Direct-Seed and Precision-Farming Field Day, Washington State University Cooperative Extension, and U.S. Department of Agriculture, Agricultural Research Service, June 2001.
7. Allen-King, R.M., C.K. Keller, T.P. Van Biersel, J.L. Smith, M. Flury, M.E. Barber, and A.N. Simmons, 2001, Water Quality on the Palouse: Field to Basin Scales, Invited Presentation at Washington State Society of Professional Soil Scientists Annual Meeting, July 2001.
8. Allen-King,R.M., 2001, Pollutant Transport Pathways from Agricultural Fields to Surface Waters: Considering the Problem at Field and Basin Scales, Invited Presentation, U.S. Geological Survey, Menlo Park, California, May 8, 2001.
9. Allen-King, R.M., 2001, Pollutant Transport Pathways from Agricultural Fields to Surface Waters: Considering the Problem at Field and Basin Scales, Invited Presentation, U.S. Geological Survey, Tacoma, Washington, October 2001.
10. Allen-King, R.M., 2002, Field to Basin Scale Chemical Mass Discharge in a Semi Arid Dryland Agricultural System, Invited Presentation, University of California, Davis, California, March 14, 2002.

PROBLEM AND RESEARCH OBJECTIVES

The purpose of this research is to use environmental tracers to quantify and predict the contributions of subsurface and surface runoff to observed loading of non-point pollutants to streams at multiple scales of study (field to basin) in a dry land agricultural setting near Pullman, Washington. These loading contributions will be compared to predictions obtained employing a GIS-based solute transport model. Both kinds of predictive models will use field-scale measurements to quantify source terms. Overall goals are to examine the scaling behavior of the observed loading, and to develop capability to model this behavior.

METHODOLOGY

Flow and Chemistry

The study area is the Missouri Flat Creek watershed, a 14,400 ha agricultural watershed. Nitrogen fertilizer is generally applied to fields in the fall or spring at rates up to ~125 kg/ha. Ground and surface water samples are collected at approximately two-week intervals from an ephemeral stream and a tile drain located in actively farmed and topographically constrained fields (~20 ha), and from seven stream-gauging stations located along Missouri Flat Creek. Surface water discharge is monitored continuously. Samples are routinely analyzed for two pesticides [the insecticide lindane or *gamma*- hexachlorocyclohexane (HCH) and the herbicide triallate, S-(2,3,3-trichloroallyl) diisopropylthiocarbamate], a nutrient (nitrate), and the tracers EC and silica. Lindane is applied as a seed coating on most spring and fall crops in the region.

Surface water samples are collected using a DH-48 sampler. The samples are integrated vertically and horizontally, in accordance with U.S. Geological Survey guidelines (Sheldon, 1994). The EC is measured using a temperature-compensated electrode. Dissolved silica is analyzed by a colorimetric method, and nitrate is determined using a continuous flow analyzer. Lindane is extracted using a solid-phase microextraction technique and analyzed using gas chromatography (Schaumloffel, 2000).

The EC and dissolved silica, which are environmental tracers, will be used to separate the contributions of subsurface and surface runoff to stream flow. Two-component, ground and surface water, hydrograph separation are being performed at each scale of observation. Tile drain and ephemeral stream tracer concentrations from field plots are used to represent groundwater and surface runoff end members. The model is:

$$Q_S = Q_{RO} + Q_{GW} \tag{1}$$

$$Q_S\, C_S = Q_{RO}\, C_{RO} + Q_{GW}\, C_{GW} \tag{2}$$

where: Q_S, Q_{RO}, and Q_{GW} are the volumetric water discharges for the total observed surface discharge (creek), unknown surface runoff and groundwater contributions, respectively; and C_S, C_{RO} , and C_{GW} are the observed concentrations for the total observed surface discharge (creek), surface runoff and groundwater contributions, respectively.

Solute Transport Modeling

Based on the digital elevation model (DEM) of the Palouse River basin, a delineation of the sub watersheds within the basin was conducted. Three watersheds were selected to represent different scales ranging from field to small-size and large-size watersheds. The large-size watershed was selected to be the whole Palouse River Basin (~ 6500 km^2). The medium-size watershed was selected to be the Missouri Flat Creek watershed (70 km^2). A small 6.5 km^2 watershed within the Missouri Flat Creek watershed represented the field scale. The DEM was also used to calculate other important topographic functions (e.g., slope, aspect and hill shade) for the three selected watersheds. The Stream Network within the watersheds was generated using the U.S. Environmental Protection Agency River Reach File 3 database. Land use and land cover information for the study area were obtained using the U.S. Geological Survey 1:250,000 scale LULC maps. These data were organized and stored into ArcView GIS shapefiles.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Flow and Chemistry

Observed lindane concentrations in the different hydrologic reservoirs ranged over approximately two orders of magnitude, from typically less than the detection limit (approximately 0.05 mu g/L) in most soil pore water and groundwater samples to a weighted mean of 0.25 mu grams/liter in field (ephemeral stream) surface runoff. The lindane $C_{RO}:C_{GW}$ is greater than approximately 100 while the ratio for silica is approximately 0.5 (silica C_{GW}.=47 mg/L). Nitrate concentrations are dynamic, generally increasing with flow, and attaining levels of several tens of mg/L. Surface water flows ephemerally a few months (approximately January to April) of the year. Groundwater discharge is observed (as tile drainage) throughout most of the year.

At the field scale, observed nitrate and pesticide concentration patterns strongly suggest that preferential flow paths and pore-scale chemodynamics are important, as one might expect in a loess soil. We envision a scenario consistent with our field observations that we are now testing, using silica and EC tracers to separate hydrographs (Equations 1 and 2). During the seasonal wetting cycle following fall fertilization, shallow soil pore water has an extremely high NO_3 concentration (averaging approximately 70 to 90 mgN/L) and relatively high SiO_2 concentration (approximately 45to 65 mg/L). Transmission of highly diluted parcels of this water can occur as bypass flow through intermittently wet macropores. This is qualitatively consistent with observed triallate and lindane transmission to approximately one-meter depth during the soil wetting cycle following fall application and with local studies showing that vertical flow in macropores can transport dye four-meter depth below the ground surface in one season, and that such transport is influenced by horizonation. Palouse soils typically approach saturation during much of the high-runoff season, and in this state the applied N, which resides as NO_3 predominantly in the solution phase, becomes diluted by a factor of three or more. The SiO_2 concentration, which originates from a dominantly solid phase reservoir that equilibrates rapidly with the solution phase is maintained at an approximately consistent value. Thus, the soil wetting, presumably with new water, serves to diminish the NO_3:SiO_2 ratio in ephemeral stream water as well as to allow the macropores to become more frequently active preferential flow paths that "pulse" quantities of the N-enriched shallow pore water to tile drains during the wettest part of the year (approximately February to May).

Future work will emphasize prediction of pesticide and nitrate mass discharges, based on tracer-based hydrograph separations and observed groundwater and surface runoff chemistries. Comparison of these predictions to measured mass discharges will help identify gaps in our understanding of the controlling processes.

Solute Transport Modeling

The analysis of the digital soil map data started with the field and the small-size watershed (i.e., the Missouri Flat Creek). Even at that scale, the number and complexity of the distribution of the soil map units (48 map units and 760 polygons) poses a great challenge to the simulation of water and solute transport if the spatial variability of the soil properties is taken into account. Therefore, the map units with similar geologic and taxonomic properties were combined together and a consolidated soil map was produced. The consolidation was made based on pedological information from the different soil map units. The consolidated map contained 12 map units and about half the number of the original soil polygons. We have represented the collected topographical, hydrological, and pedological information in form of a series of maps, each of them at three different scales. The maps show the change of geographical information when going from one scale to the other and will build the foundation for the future modeling work. In this work, the spatial variability in soil properties will be quantitatively evaluated by providing a standard soil profile description for every map unit. Soil properties will then be averaged over all layers and combined using the weighted average for all the components within the map unit. These average values will be used as the input parameters for selected flow and transport models. Model drainage of water and solutes will be carried out to assess loading behavior. Field-scale data (*Flow and Chemistry*, above) will be used to calibrate and validate the models. Simulation of water and solute transport at different scales will be performed and the effect of the spatial variability in soil properties will be examined. Simulation will also test the sensitivity of solute transport to the spatial delineation of soil map units.

A Watershed Scale Study on No-till Farming Systems for Reducing Sediment Delivery

Basic Information

Title:	A Watershed Scale Study on No-till Farming Systems for Reducing Sediment Delivery
Project Number:	1999WA0014G
Start Date:	9/1/1999
End Date:	8/31/2003
Funding Source:	104B
Congressional District:	5th
Research Category:	Water Quality
Focus Category:	Sediments, Agriculture, Models
Descriptors:	Sediment Delivery, Best Management Practice, Watershed, Soil Erosion, Water Quality, Watershed Management, Runoff, Conservation Farming
Principal Investigators:	Shulin Chen

Publication

1. Wang, G., S. Chen, J. Boll, C. Stockle, and D. McCool, 2002, Modeling Overland Flow Based on Saint-Venant Equations for a Discretized Hillslope System, Hydrological Processes, 16(12):2409-2421.
2. Mancilla, Gabriel, 2001, Prediction of Rill Density, Transport Capacity and Associated Soil Loss of Different Tillage Systems Under Winter Conditions, "MS Dissertation," Department of Biological Systems Engineering, College of Engineering and Architecture, Washington State University, Pullman, Washington, 80 pp.
3. Mancilla, Gabriel, Shulin Chen, and Don McCool, 2001, Flow Velocity and Rill Density Distributions from Runoff on Agricultural Land, "in" Proceedings, ASAE Annual International Meeting, July 30-August 1, 2001, Sacramento, California, ASAE Paper 01-012078.
4. Mancilla, Gabriel, Shulin Chen, and Don McCool, 2002, Soil Loss Prediction Under Different Tillage Systems, Based on the Estimation of Rill Density, Flow Velocity Distributions and Transport Capacity, "in" Proceedings, Research and Extension Regional Water Quality Conference, February 20-21, 2002, Vancouver, Washington, State of Washington Water Research Center, Washington State University, Pullman, Washington, 3 pp.

PROBLEM AND RESEARCH OBJECTIVES

This project addresses priority areas of water research in the Pacific Northwest. The increasing listing of salmon species as threatened or endangered by the National Marine Fisheries Service, under provisions of the Endangered Species Act, has profound impacts to agricultural practices and agriculture sustainability. The Northwest Wheat and Range Region (NWRR) has one of the highest soil erosion levels of the United States. Freezing and thawing cycles of the ground favors the detachment of soil particles and make them easier to be transported by runoff. In addition, currently practiced farming systems tend to leave the soil unprotected to the rain energy. Protecting fish habitat, by controlling soil loss and associated sediment and chemical loading to the streams, is a major challenge to the farmers in this region. No-till farming has been recommended to farmers as a conservation culture practice to reduce soil erosion. The effectiveness of this practice, however, has not been evaluated at a watershed scale.

Another important soil erosion-related issue is sediment delivery. One of the questions that farmers often ask is "what is the percentage of eroded soil that ultimately ends up in streams?" For a large area in northern Idaho, eastern Oregon and eastern Washington, which is typified by steep rolling hills, as well as freezing and thawing winter conditions, sediment delivery ratios have not been well studied. As a result, there is a lack of basic modeling tools for the purpose of planning, management, and policy development for these agricultural watersheds.

Objectives

1. Compare soil loss from non-till and traditional farming fields
2. Evaluate models for sediment delivery process under no-till and traditional farming conditions.
3. Develop a model for predicting sediment delivery of the entire watershed.

METHODOLOGY

Runoff Plot Study

The purpose of the runoff study is to investigate the difference between no-till and conventional tillage systems in terms of the amount of runoff produced for a given rainfall. One-square meter runoff plots with borders and runoff collectors were installed in Pataha Watershed in areas of different levels of precipitation. In the 2001-2002 season, the high precipitation area had the greatest number of plots installed on seven sites: a forest site, a conventional tillage with deep furrow seeding field, a disked no-till site, two no-till standing stubble sites, and two planted no-till sites. The intermediate precipitation area had plots installed on two sites: a new no-till previous conventional tillage site with chemical fallow, and a no-till stubble area. Frost tubes, a Belfort chart recorder precipitation gauge, an automated weather station (this one operated by the conservation district), and manually read precipitation gages were installed adjacent to the sites. The low precipitation area had plots installed on three sites: a no-till seeded, a chemical fallow no-till seeded and a conventional tillage seeded. The sites were instrumented with frost tubes and manually read precipitation gauges. Plot were served by monitoring the volume of water in the runoff collectors attached to the plots, as well as checking and correcting the plot borders for frost heaving, and for overflow or underflow conditions.

In addition to those installed in the Pataha watershed, plots of different sizes were also installed, during the season 2001-2002, in a small watershed located next to the Pullman-Moscow airport, and managed with conventional tillage. The plots, with dimensions of 5.5, 11 and 16.5 m^2 respectively, were employed to determine runoff and the soil loss generated. An automatic sampler, bubbler water level recorders and an automatic weather station and frost tubes were also installed in the watershed.

Hydrological Study

The flow rates of the two watersheds were continuously monitored. Five ISCO water level recorders were installed in the main Pataha Creek at Columbia Center, Tatman, and Marengo, and at the tributaries in Benjamin Gulch, and Houser's separately. These devices contain memory units that store the data that can be then downloaded to a computer for processing. In some of the areas it was necessary to install also flumes to ease the determinations of discharge and to solve, in part, the irregularities of the watercourse bed. Velocity-area measurements were conducted in the specified sections to obtain the calibration curves that provide the relationships between discharge rates and water levels. In the Pullman-Moscow airport watershed, an ISCO bubbler water level recorder was installed in the two main watercourses. The flow measurement devices were maintained weekly (or every two weeks) and flow data were downloaded.

Soil Erosion, Rill Formation and Sediment Delivery Study

As rill erosion is the main mechanisms for soil loss in the study region, a comparative study of rill formation in different tillage systems was conducted to determine the field soil loss rate and sediment transport within the rill at the USDA Palouse Conservation Field Station, Washington, in the season 2000-2001. In this study, the runoff was generated artificially. During the report period, monitoring systems were implemented in the Pataha Watershed to measure the sediment delivery from sub-watersheds. The monitoring devices were installed in different sub-watersheds, one with primarily no-till practice and the other with mostly conventional tillage system. Major instrumentation installed included water level recorders, automated sampler systems, recording precipitation gauge, frost tubes, and manually read precipitation gauges. The automated samplers allowed us to obtain samples continuously of the flow at a specified frequency or depending on the flow level, as programmed. Samplers were installed at the same areas where the water level recorders were located.

Hydrological and Sediment Delivery Modeling

The integrated watershed hydrological model framework was completed, including the overland flow model and a channel routing model. A process-based hydrologic modeling framework using Saint-Venant equations has been developed for overland flow routing. Saint-Venant equations include a continuity equation and a momentum equation. For the study region, with low precipitation intensities, the momentum equation was replaced by the Chezy equation.

Details on these equations were given in the previous report. A solution for these equations was performed analytical and numerically (by applying Runge-Kutta algorithm). The overland flow prediction by the model fitted well with the field data. A sediment transport model is currently being developed based on rill and interrill physical processes to predict sediment delivery to the main channel for a sub-watershed of Pataha located near Pomeroy. In the Pullman-Moscow airport watershed, however, the lack of a consistent soil erosion process in the past seasons requires the generation of artificial rain and runoff in order to collect more data. The models will be verified with the data from the correspondent area.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Objective 1

Runoff produced in the 21 plots of all the wheat fields during the 1999-2000 winter season was about 18 percent of the total precipitation. The rest of the water was considered as infiltrated. The relatively small runoff produced could be due to the fact that most of the precipitation was as snow, with a long period of accumulation and melting. Freezing was observed to cause soil cracking, enhancing infiltration of water while the snow was melting. Sediment concentrations in runoff were generally higher in conventional tillage fields, so was the total amounts of solids. These facts reveal that the soil erosion was effectively reduced by no-till practice, even though the runoff differences between cropping practices were not evident. In only one pair of areas, the no-till practice showed more erosion than the conventional one.

Data collection and analysis continued for the 2000-2001 winter season. Unfortunately, the watershed experienced an exceedingly mild winter for this season. Neither of the subwatershed monitoring systems reported sufficient discharge to trigger water sampler operation. In fact, the subwatershed monitoring system in the Linville Gulch area did not report any discharge at all.

For the 2001-2002 Season, in the high precipitation zone plots on Pataha watershed, the runoff was about 30% of the total precipitation. Almost 90% of the runoff recorded was generated in the plots located at the conventional tillage site. However, no major evidence of soil erosion was found, which indicates that the runoff did not reach the rates and velocities that could produce sufficient energy for detachment and transport of sediments. In the same way, the none presence of rills made hardly possible that the runoff could reach the main channels and streams, being most probably infiltrated in some points of the fields. On the other hand, no runoff was recorded in the intermediate precipitation zone, while in the low precipitation areas the runoff was less than 1% of the precipitation.

The Pullman-Moscow airport the watershed showed some similar patterns as the Pataha watershed in terms of runoff. In fact, there was not recorded runoff in any of the different size plots installed at diverse sections of the hills, so all the water was considered infiltrated into the ground, then moved through subsurface flow to the main channels. In this watershed, however, there were some observed special features. In some points, especially in areas of depression, the ground surface was unable to store too much water, so flow was generated by oversaturation and movement of pounded water, but not coming as surface runoff from the upper sections of the hills. In such a way, some rills were formed by the concentrated flow in the depression areas, mostly following the tillage paths. The water ran through the rill and reached the main channel, detaching and carrying soil particles along. The rills however, only formed in limited areas where suffered some erosion. Preliminary runoff estimations indicated that between 38 and more than 80% of the flow in the main channels could come from the rills in the rainfall/snowmelt events. On the other hand, the ratio of soil loss concentration between rills and the main channel varied between close to 11% and more than 55%, with the lower proportions normally occurred when the flow levels were higher (or the rill cross sectional area was smaller), probably due to the increase in the bed erosion in the main channel.

Objective 2

The results of the experiments conducted with artificial runoff during the 2000-2001 winter season at the USDA Palouse Conservation Field Station showed the importance of no-till system as an effective way for controlling rill formation and soil erosion. In fact, it was almost impossible that a rill was formed in no-till areas, even with the application of large amounts of runoff. On the other hand, in conventional tillage areas it was found that as many as three rills per meter could form.

In the 2001-2002 season no experiments with artificial runoff were performed. As explained before, the nature of the snow and precipitation events in the season was very favorable in terms of soil erosion control and there was practically no soil loss. However, the only evidences of rill formation in the Pataha watershed was found in a conventional tilled field, as well as in the Pullman-Moscow airport watershed. Therefore, even in the fair conditions of the rainfall and snow events, conventional tillage areas were the only ones showing some activity and delivering sediment to the main channels.

Objective 3

A sediment delivery model must integrate two main sub-models: the sediment transport and the hydrological models. The hydrological model has been developed using an integrated watershed system approach. Using this approach, a watershed of interest will be divided into lower level subwatersheds based on rainfall distribution and physical geographical conditions. Implicit analytical solution for kinematic wave equation was used to calculate outflow hydrograph of the lowest order's sub-watershed. For main channel routing, a mixing cell method was used to transform the convection diffusion equation derived from the complete Saint-Venant equation into first-order nonlinear ordinary differential equation that is solved using Runge-Kutta method. The parameters for the model need limited calibration, as they are determined based on the physical geographical conditions of a watershed.

The framework for the sediment transport model has began to be developed in the report period by studying alternative equations that could fit the predominate processes in the region. Due to the weather-related factors, the lack of erosion data makes highly necessary to use artificial rain in order to create the conditions to investigate the movement of sediments and to calibrate the model developed.

In addition, the implementation of the modeling framework in term of computer programming and integration with a GIS system has been initiated. The computer model will integrate the results of hydrological and sediment transport modeling with interfacing with the graphic and mapping tools of the GIS. In fact, a GIS procedure to delineate lower levels of hydrologic units has been developed based on the natural watercourses more than the DEM. This is an improvement to the current practices. This new procedure allows more accurate determination of the stream network than relying only on DEM during watershed simulation. The respective codes development for the computer model has began and the first version of the program is expected by the end of 2002.

Biodegradation of Non-Point Source Pollutants in Soap Lake, Washington

Basic Information

Title:	Biodegradation of Non-Point Source Pollutants in Soap Lake, Washington
Project Number:	2001WA781B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	
Congressional District:	WA 5th
Research Category:	
Focus Category:	Non Point Pollution, Toxic Substances, Water Quality
Descriptors:	Pollutants, Toxic Substances, Water Quality, Biodegradation, Arid Climates, Alkaline,Saline
Principal Investigators:	Brent Michael Peyton, David R Yonge

Publication

1. Peyton, Brent M., and David R. Yonge, 2002, Biodegradation of Non-Point Source Pollutants in Soap Lake, Washington, State of Washington Water Research Center, Washington State University, Pullman, Washington, 39 pp.
2. Peyton, Brent M., Victor A. Alva, Celso Oie, and Melanie R. Mormile, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria from Soap Lake, Washington, "in" Proceedings of Research and Extension Regional Water Quality Conference 2002, February 20-21, 2002, Vancouver, Washington, State of Washington Water Research Center, Washington State University, Pullman, Washington, 3 pp.
3. Alva, Victor A., Brent M. Peyton, and Celso Oie, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria from Soap Lake, Washington, Invited Presentation at the Inter-Government Conference on Soap Lake, Soap Lake, Washington, April 26, 2002.
4. Peyton, Brent M., Victor A. Alva, Celso Oie, and Melanie Mormile, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria from Soap Lake, Washington, Invited Presentation at the Washington State Lake Protection Association 15th Annual Conference on Lakes, Reservoirs, and Watersheds, Olympia, Washington, April 3-5, 2002.
5. Peyton, Brent M., Melanie R. Mormile, Victor A. Alva, Celso Oie, F. Roberto, and W. A. Apel, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria,

Presentation at the International Conference on Halophilic Microorganisms, Seville, Spain, September, 2001.

PROBLEM AND RESEARCH OBJECTIVES

Soap Lake

Soap Lake is a highly saline and alkaline meromictic lake located in the Lower Grand Coulee area of Eastern Washington State. Because of local aridity, the Coulee lies in a region of internal drainage, in which surface streams dry out before they reach the ocean or a major river. Soap Lake is the southernmost lake in a chain of lakes of increasing salinity from north to south (Pickett, 1999). While there is no surface water inlet or outlet, there is water recharge from groundwater seepage, precipitation and runoff. (Anderson, 1958; Edmonson, 1991).

Human activity from transportation (highway runoff) and livestock activity (organic wastes) may contribute to increasing pollution in the area surrounding of the lake. Pollutants originating from those activities may affect the ecology of the lake leading to eutrophic conditions that could threaten the life of the indigenous and unique living organisms that thrive in this extreme environment. To date, very little is known about the biodiversity of the lake, its relationship with the dynamics of the lake and its effect in the lake global ecology.

Measurements of Soap Lake pH with depth indicate that the pH values remain very constant at 9.8 to 10 year round throughout the water column. However, it is known that at least three very distinct macro-environments exist in the lake. These three environments, the mixolimnion, chemocline, and the monimolimnion exhibit very significant differences in ionic strength (20,000 to 140,000 mg/L total dissolved solids), temperature (6-20^{o}C), and dissolved oxygen concentration (8-0 mg/L).

Influx of Pollutants to Saline-Alkaline Environments

In the last 30 years, saline-alkaline lakes as well as fresh water bodies have been protected as part of the nationwide effort to reduce the impacts of contaminant discharges into the environment. Point source pollutant control, promulgated by the 1972 Clean Water Act, has been an effective means of reducing contaminant input into the environment. Unfortunately, non-point control has not progressed at the same rate and, as a result, is a major source of pollution in large areas of the U.S. (U.S. Geological Survey, 1999). In the early 1990s, a Federal water quality initiative was developed with the goal of protecting the nation's waters from nutrient and pesticide contamination. An extensive water quality sampling campaign (National Water Quality Assessment Program) was carried out as part of this initiative, resulting in a significant database of information regarding contaminant type and concentration in surface and groundwater. However, saline and alkaline lakes were ignored in the sampling initiative, presumably because these environments were not considered relevant to the nation's recreational or potable water supplies. Pollutant type and concentration that are likely entering saline-alkaline lakes from non-point sources are primarily a function of local and regional land use. The primary land uses that generate pollutant-bearing runoff include agriculture, urban areas, and highways. As would be expected, agricultural activities generate runoff that contains sediment, pesticides, and nutrients. Numerous PAHs have been detected in highway and urban runoff. Those most frequently detected in Washington State are: pyrene, phenanthrene, fluoranthene, and chrysene (Yonge et al. 2002).

Information regarding the fate and impact of agricultural, highway, and urban pollutants on biological communities in extreme environments is very scarce. Even for neutral pH and low salinity waters, current standards and guidelines are limited to only a relatively few pollutants and do not account for contaminant mixture effects or the effects of long-term, low-level exposure. In addition, guidelines that are "safe" for aquatic systems of low salinity and circumneutral pH may not apply to saline-alkaline ecosystems that may be more sensitive to the influx of contaminants or may altogether lack the degradative capability to remove particular contaminants. The research conducted here will benefit state regulators, concerned citizens, and the scientific community by meeting the following work scope and objectives:

1) A small number of samples were collected to screen for non-point source contaminants present in Soap Lake water and sediments. Samples were sent to an environmental laboratory to determine the type and concentration of contaminants currently present in the lake.
2) Microbial degradation rates of selected non-point source contaminants were quantified in laboratory tests with mixed cultures of Soap Lake bacteria. Our overall goal was to develop data that begin to elucidate the potential impacts of non-point source pollutants on extreme environments like Soap Lake. The ability of these potentially fragile ecosystems to tolerate these contaminants is largely unknown. Our results significantly improve the current understanding of the impacts and interactions between specific anthropogenic contaminants and the haloalkaliphilic bacteria found in Soap Lake. For the scientific community, our results will provide some insight into haloalkaliphilic environments throughout the West that are potentially threatened by anthropogenic pollutants.

METHODOLOGY

Three locations in Soap Lake were sampled for water and sediment in May 2001. Samples were collected from the deepest part of the lake in the monimolimnion and overlying chemocline and mixolimnion, and from two much shallower sites in the mixolimnion. The first sampling point (P1) was in the southern part of the lake (GPS coordinates N 47 25' 9" W 119 3' 23"), the second (P2) at the central part (coordinates N 47 24' 39" W 119 30' 5") and the third point (P3) was at the northern part of the lake (coordinates N 47 23' 20" W 119 29' 11"). Samples of both water and sediments (identified as S) were collected. At the central part of the lake (P2), samples were taken at 10, 20, 24, and 26 m. Samples from these points are identified as P2-10, P2-20, P2-24 and P2-26, respectively.

Collected samples were used to challenge the native microbial communities with selected contaminants. In addition, chemical analyses were performed to characterize the bulk water chemistry (pH, O_2, temperature, and conductivity) and to detect the possible presence of anthropogenic PAH and pesticide contaminants. An existing Hydrolab Surveyor 3 connected to a field data logger was used to measure pH, temperature, conductivity and dissolved oxygen. Water and sediment samples for aerobic microbial enrichments were immediately transferred to previously sterilized HDPE bottles and cooled to 4^oC. All samples were kept on ice until they reached our laboratories in Pullman,Washington, on the same day as they were collected.

Individual PAHs and atrazine concentrations were measured using a Hewlett Packard Series 1100 high-pressure liquid chromatograph (HPLC). Degradation tests were performed under aerobic and anaerobic conditions. Tests were carried out in a temperature-controlled chamber, with the flasks shaken at 150 rpm in the dark. For each set of experiments, abiotic controls were run in parallel. Additional anaerobic tests were also carried out with addition of a mixture of thioglycolate and citric acid, used as an oxygen scavenger. In the screening experiments with PAHs and atrazine, the water from the lake was used as media for degradation experiments. In further experiments with atrazine, artificial media with 4 different compositions were also tested to verify the ability of the microorganisms to grow in different concentrations of sulfate, sodium chloride and carbonate.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The amount of Total Dissolved Solids (TDS) in the lake increases from 15,000 mg/L in the mixolimnion to 130,000 mg/L in the monilimniom. The most important ions are sodium, chloride and sulfate. Sodium increases from 4,500 mg/L (0.2M) in the mixolimnion to 38,000 mg/L (1.6 M) in the monilimniom, which qualifies this lake as a moderate halophilic environment (Ventosa et al, 1998). In addition, the high concentration of sulfate in the monilimniom and the strong sulfide odor, may indicate the presence of microbial communities of sulfate reducing bacteria that use sulfate as electron acceptor in their metabolism.

Contaminants

PAH analysis performed by Sound Analytic Services (Tacoma, WA) indicated no presence of PAHs or pesticides in the liquid samples. However, sediment samples showed low level traces of phenathrene (P2-S), and the pesticides DDT, dieldrin and endrin (P3-S).

Biodegradation tests

Experiments performed aerobically with phenol as a control in water from Soap Lake demonstrated that almost all the samples collected from the lake degraded phenol completely in less than 12 days. Only the samples from the bottom of the lake did not degrade any of the phenol. Degradation experiments under anaerobic conditions with lake water from the depth of 26 meters (P2-26) provided negative results for phenol.

From the 9 samples tested for phenanthrene, only one sample resulted in any degradation after 120 days. The sample P2-10, collected at sampling point 2 and at a depth of 10 m, resulted in almost 60% degradation over the 120 day incubation period. Results with fluoranthene were similar to phenanthrene, but in this case, only the sample P2-26 presented slight degradation capacity for this substrate. After 84 days, approximately 50% of the substrate was degraded. These results indicate that if significant amounts of PAH pollutants were allowed to enter the lake, these compounds may be very long lived and in fact the PAH, phenanthrene, was one of the few contaminants detected in Soap Lake sediments.

Atrazine provided the best degradation results in the screening tests, and was studied in more detail. In the screening tests, water from the lake was used as the medium for atrazine degradation. The cultures present in the anaerobic sample P2-26 demonstrated the highest capacity to degrade atrazine. With an initial concentration of 23 mg/L, at 6^{o}C, complete degradation occurred after 170 h, while at 30°C complete atrazine degradation took 50 h. These microorganisms also demonstrated high adaptability to changes in media composition, indicating the ability to degrade atrazine in different conditions.

In summary, these results are an important step in the study of non-point pollutants and their biodegradability in environments of extreme pH and salinity. While phenol and atrazine were degradable under some conditions, phenanthrene and fluoranthene (both PAH's) do not appear to be generally biodegradable under high salt and high pH conditions found in Soap Lake. These results may be important to designing unique protection strategies for Soap Lake (an other extreme environments in the Northwest) that may not be adequately protected from contaminant influx at this time.

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Dye Tracers for Vadose Zone Hydrology

Basic Information

Title:	Dye Tracers for Vadose Zone Hydrology
Project Number:	2001WA1041B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	5th
Research Category:	Water Quality
Focus Category:	Solute Transport, Water Quality, Hydrology
Descriptors:	Solute Transport, Groundwater Quality
Principal Investigators:	Markus Flury, James Harsh

Publication

1. Flury, Markus, and James Harsh, 2002, Dye Tracers for Vadose Zone Hydrology, State of Washington Water Research Center, Washington State University, Pullman, Washington, 25 pp.

PROBLEM AND RESEARCH OBJECTIVES

The solutions to many of the critical regional or state water problems rely on experimental data collection. Point and non-point source groundwater pollution, chemical transport in surface and subsurface waters, irrigation-related water quality and distribution problems, to name a few, can be addressed to some degree by the experimental investigation of water flow pathways and travel times. In hydrological research and hydrology, tracers have played a significant role in elucidating our current understanding of the hydrological cycle and subsurface flow and transport processes. Tracers are used to investigate flow pathways, to estimate travel and residence times, or to assess risks associated with pollution. While a wide variety of different tracers are frequently used, dyes have been, and are still, among the most prominent subsurface water tracers. The main reasons for the use of dyes in hydrological research are the ease of detection at low concentrations in aqueous solution, the possibility to visualize the flow pattern in rivers, and soils and the ease of quantification by chemical analysis. Hundreds of dyes are commercially available, and many may be potentially useful as hydrological tracers. Only few of the currently available dyes have been used and tested as hydrological tracers.

The objective of this study was to evaluate four selected dyes in respect to their suitability as hydrological tracers. Specifically, we address the following objectives:

1. Measure sorption and transport behavior of selected organic dyes using laboratory batch and column studies.
2. Compare adsorption isotherms measured by batch and column experiments.

METHODOLOGY

Four dyes with the same molecular backbone but different substituent groups, i.e., type, number and position were used in this study. These dyes were commercially available in solid forms and obtained directly from manufacturers. All the four dyes are from the same chemical class of Triphenylmethane.

Column experiments were performed under water saturated conditions. An Omnifit glass chromatography column with an inner diameter of 1.5 cm and the length between the top and the bottom plates of 12.2 cm was used in the experiment. The end plates of the column consisted of porous polypropylene disks to assure uniform flow within the column. The inlet end of the column was connected to a pump that allows flow rate adjustments and the outlet end was connected to a fraction collector (LKB Bromma, 7000 Ultrorac, Sweden). Teflon tubings with an inner diameter of 1.5 mm and 0.75 mm were used to connect the inlet to the pump and the outlet to the fraction collector, respectively.

A pulse-input was used to introduce chemicals into the column. Calcium nitrate [$Ca(NO_3)_2$] and dyes used in the experiments were dissolved in the background solution (0.01 M $CaCl_2$). The concentrations of nitrate and dye solution were 0.01 mmol L^{-1} and 2.5-2.9 mmol L^{-1} (2 g L^{-1}), respectively. The effluent of the column was collected in glass culture tubes with the fraction collector. Because some degree of impurity was observed in the Acid Blue 7 dye sample, the dye solution was sequentially filtered using 11 μm filter paper (Whatman Ltd., UK) and with a 0.4

μm membrane filter (Nuclepore Corporation., CA) before introduction to the column Relative concentration (outflow concentration/ input concentration) and numbers of pore volume were plotted to obtain nitrate breakthrough curves, but the actual dye concentrations of column outflow were plotted against the numbers of pore volume to obtain dye breakthrough curves.

Batch experiments were performed using nine different dye concentrations ranging from 0.0001to 2.9 mmol L^{-1} (0.1, 1, 10, 50, 100, 200, 500, 1000, 2000 mg L^{-1}) and two solid-solution ratios (1:6, 1:1). The solid-solution ratio of 1:6, where 10 g of soil was shaken with 60 mL of dye solution, was used at the concentration range from ~0.0001 to 0.0015 mmol L^{-1} (0.1 to 10 mg L^{-1}). However, 20 g of soil was shaken with 20 mL of dye solution (1:1 ratio) at the concentration above 0.015 mmol L^{-1}. The requirement of a different solid-solution ratio at high concentrations is because of adsorbed dye concentration in the samples with 1:6 ratio was very small compared to the input concentration and found to be in the range of the measurement error.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The hydrodynamics of the column was indicated by the Peclet number calculated from the nitrate breakthrough curves. The Peclet number for the first and the second column were 150.7 ± 0.77 and 146.6 ± 0.71, respectively. The breakthrough data fit the model parameter well. The Peclet numbers of both columns were relatively high, so that it is reasonable to ignore the dispersion term in the convection-dispersion equation used for calculation of adsorption isotherms.

A comparison of dye breakthrough curves showed that the dye fronts of the Food Blue 2 and Food Green 3 closely follow one after another and the breakthrough occurs at about 2.5 to 3 pore volumes. The breakthroughs of the Acid Blue 7 and Acid Green 9, however, occur at about 5 to 6 pore volumes. Unlike in the case of other three dyes, the maximum concentration in the outflow of the Acid Green 9 was measured only about one half of the input concentration. As of the adsorption isotherms, for the input concentration used in the experiments, the maximum sorbed concentration for the Food Blue 2 and Food Green 3 was ~0.5 mmol kg^{-1} and for the Acid Green 9 and Acid Blue 7 were ~1.6 and ~3 mmol kg^{-1}, respectively. Food Green 3 seems to be less absorbed compared to Food Blue 2. The sorbed concentration of the Acid Green 9 was lower than that of Acid Blue 7. However, column breakthroughs of these two dyes suggest a contrasting result that the breakthrough of the Acid Blue 7 occurred earlier than that of the Acid Green 9. The evidence suggested that sorbed concentration of Acid Green 9 showed by column data might be under estimated and more associated with experimental errors.

Adsorption isotherms calculated from column data do not agree very well with those obtained from batch studies. With an exception to the Acid Green 9, the sorbed concentrations calculated from column data were higher than that of batch studies. On a linear scale, column and batch techniques more likely agree at lower concentration part of the isotherms, but column data tend to over estimate the sorbed concentrations at the high concentration portion of the curves. On a double logarithmic scale, however, isotherms measured with the two methods tend to have a good agreement at the high concentration zone of the isotherms. Column data again seem to over estimate the sorbed concentrations in the lower concentration portion of the curves.

Based on the results obtained from both column and batch studies, Food Blue 2 and Food Green 3 were less adsorbed than Acid Blue 7 and Acid Green 9 on the Vantage sand medium. The main difference among these four dyes is the number of sulfonic acid groups in their structures. As previously mentioned, Food Blue 2 and Food Green 3 consists of three sulfonic acid groups but Acid Blue 7 and Acid Green 9 contains only two. Adsorptions of these dyes on a soil medium agreed with previous findings that dyes consisted of more sulfonic acid groups tend to be less sorbed and have a better mobility in soil. However, further studies is needed to be able to explain why the adsorption of dyes with the same number of sulfonic acid groups, e.g., Acid Blue 7 and Acid Green 9, differs from one another. The difference in position of sulfonic acid groups in the molecular structure might also influence the sorption of these tested dyes in soil. Not only the number and position of sulfonic acid groups, but containing different substituent groups might also effect the sorption of the dyes. For instance, Food Green 3 tends to be less adsorbed compared to the Food Blue 2 although they contain the same numbers of sulfonic acid group at exactly the same positions on the molecular backbones. The only structural difference between these two dyes is that Food Green 3 consists of one hydroxyl group, but Food Blue 2 does not.

Information Transfer Program

The Water Research Center believes that Outreach and Education are important components to its mission. The primary goal is to facilitate information exchange by providing opportunities for combining the academic work of research universities in the state with potential users and water stakeholders. This process occurs through a variety of activities, formal and informal, that raise the visibility of university research results throughout the Pacific Northwest. Federal, state and local agencies, non-governmental organizations, watershed groups, and concerned citizens are in need of interpreted science that can be applied to solving the regions water problems. The Center makes substantial efforts to facilitate this process.

Statewide Outreach and Information Transfer

Basic Information

Title:	Statewide Outreach and Information Transfer
Project Number:	2001WA2061B
Start Date:	3/1/2001
End Date:	2/28/2004
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Research Category:	Not Applicable
Focus Category:	Management and Planning, Education, None
Descriptors:	Electronic Publishing, Information Transfer, Statewide Outreach
Principal Investigators:	Michael Ernest Barber

Publication

1. Proceedings of 2002 Research and Extension Regional Water Quality Conference, 2002. Compiled and edited by the State of Washington Water Research Center. February 20-21, 2002, Vancouver, Washington. State of Washington Water Research Center, Pullman, Washington, Report No. 103. (CD)

The following items constitute the core of the technology transfer activities of the center.

1. A regional water quality conference was held in connection with a USDA-CSREES funded grant. The main objective of the conference was to present current science and scientific advances as well as their practical application for technology transfer and outreach. Over 170 individuals from extension, university faculty, consultants, and technical personnel for state and federal agencies came together to express their experiences in a wide variety of local water issues including animal waste management, drinking water and human health, environmental restoration, nutrient and pesticide management, pollution assessment and prevention, water quantity and policy, and watershed management.

2. Continued funding for the USDA-CSREES grant was received. The project helps coordinate research and extension activities of the Water Research Institutes and Cooperative Extension Services in Alaska, Oregon, Idaho, and Washington with EPA Region 10. Bi-monthly meetings are held, and communication between researchers and governmental agencies is expanding rapidly.

3. Washington e-Water News. This is an informative electronic newsletter that reaches over 1,500 individuals. It includes a variety of current and emerging research and extension issues presented in a format suitable for the general public. Newsletter issues 3, 4 and 5 were printed during this year. The newsletter has been extremely well received by our constituency.

4. Web page development. This is an important media for us to present information about the activities of the Center and the research faculty in the state as well as news and events, research reports, and opportunities for research funding. This media requires nearly continuous work to ensure that the material is current and the look of the page is up to date. Therefore, a great deal of effort is placed into improving and updating the page.

5. Our database of interested stakeholders is constantly being updated. Currently, over 2,000 names are included with the number growing every month.

6. A variety of other small activities are conducted such as a) presentation to watershed groups, b) service in response to telephone and e-mail requests from users, c) organization of small seminars and workshops, and d) attendace at extension and agency meetings.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	3	0	0	9
Masters	2	3	0	0	5
Ph.D.	0	5	0	0	5
Post-Doc.	0	1	0	0	1
Total	8	12	0	0	20

Notable Awards and Achievements

Publications from Prior Projects

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