Water Resources Center
Annual Technical Report
FY 2002

Introduction

Research Program

INTRODUCTION

The Water and Environmental Research Center (WERC) at the University of Alaska Fairbanks (UAF) continues to grow with the addition of new faculty, increased research grants, and graduate students. In the past couple of years we have significantly improved our workspace through a complete refurbishing of our offices and laboratories and enhanced our laboratory analytical equipment through a large private grant.

Dr. Horacio Toniolo (sediment transport) and Dr. Paras Trivedi (environmental engineering) have joined the faculty of WERC. Both will also teach in the Civil and Environmental Engineering Department.

As in past years, our philosophy for utilizing USGS dollars is to put them into graduate student support. We funded five research projects partially during the March 1, 2002 to February 28, 2003 with the funds provided by USGS:

1) Hydrological and Geomorphological Controls on Sediment Transport Processes in the Alaskan Arctic, Larry D. Hinzman PI.

2)Molecular Characterization of Organic Matter in Soil Leachates from the Caribou-Poker Creek Watershed, Daniel M. White and Kenji Yoshikawa PIs.

3) Investigation of Fouling in Membrane Bioreactors for Wastewater Treatment, Silke Schiewer PI.

4) Investigation of Immiscible Fluid Movement through Frozen Porous Media, David L. Barnes and Yuri Shur PIs.

5) Luminescent Bacteria: A New Water Quality Issue? Joan Braddock, PI.

Recently we have had numerous studies examining arctic hydrology and how it may be impacted by climate change. Obviously, a warmer climate would impact the thermal regime. But there may be other impacts such as greater precipitation (snow, rain or both?), alterations to channel networks, increased sediment transport, increased nutrient fluxes to the Arctic Ocean, greater evapotranspiration and others. NSF, DOE and NASA have funded these projects primarily.

The transport of contaminants around and through frozen soils (permafrost and seasonal frost) continues to be an important problem to be addressed. We have had projects funded by state and federal agencies and the private sector. Most of the studies are directed at areas where spills have been known to occur. Coupled with the contaminant transport is the dynamics of groundwater flow, often associated with discontinuous and continuous permafrost.

Advances in remote sensing and applications to remote areas of the Arctic continue to be a lucrative area of research. Supplementing the meager hydrologic and meteorologic data collection systems in the high latitudes with remotely sensed data products appears to be the only pathway for generating more comprehensive data sets. Remotely sensed products have been used to get detailed digital elevation data for geomorphic studies, spatially soil moisture distribution and changes in surface wetness (shrinkage of lakes, ponds and wetlands).

Although environmental researchers in the Center do not have areas of concentrated research they are addressing a wide range of subjects: PCB dechlorination, indoor air quality, mid-winter pumping of tundra lakes, fouling of membranes in bioreactors, cyanide removal, fingerprinting of soil organic material, rain catchment systems, etc.

The Center continues to grow in all directions including faculty, graduate students and external funding. From July 1, 2002 to June 30, 2003, expenditures for the Water and Environmental Research Center were approximately $2,800,000 with $750,000 in state dollars and $2,050,000 in external dollars. This represents a total expenditure increase of 8 % this year.

Investigation of Immiscible Fluid Movement Through Frozen Porous Media

Basic Information

Title:	Investigation of Immiscible Fluid Movement Through Frozen Porous Media
Project Number:	2002AK1B
Start Date:	5/1/2002
End Date:	5/8/2004
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Ground-water Flow and Transport
Focus Category:	Toxic Substances, None, None
Descriptors:	Petroleum, Frozen Soil
Principal Investigators:	David L. Barnes, Yuri Shur

Publication

1. Barnes, D.L., S.M. Wolfe, and D.M. Filler. Equilibrium Distribution of Petroleum Hydrocarbons in Freezing Ground. In Review, Polar Record.
2. Wolfe, S. M., D. L. Barnes, Y. Shur, and D. M. Filler. 2003. Two-Dimensional Movement of Immiscible Fluids Through Frozen Soil. In Proceedings of the 3rd Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates, May 5-6, 2003.
3. Barnes, D. L. and D. M. Filler. 2003. Spill Evaluation of Petroleum Products in Freezing Ground. Polar Record, 39 no. 210: 1-6.

Introduction

Frequent releases of petroleum in regions experiencing seasonal or permanent frozen ground has prompted engineers and scientists to investigate the physical and chemical aspects of immiscible fluid movement in frozen ground. An understanding of these processes is required to engineer methods for protecting both the environment and human health. In Alaska, several recent relatively large petroleum releases in areas of permanently and seasonally frozen ground illustrates the importance of gaining a better understanding of the physical and chemical processes controlling the migration of these compounds through frozen ground to possible freshwater sources.

One key facet of this topic is the relationship between structures of frozen soil (cryogenic structures), moisture content (frozen and unfrozen) and the permeability of soil to petroleum products. It is known that freezing and thawing are very important factors of soil structure. Freezing and ice formation produce cryogenic structure and desiccation of soil below freezing front leads to shrinkage and cracking of soil. Thawing of frozen soil and melting of ice inclusions does not completely destroy soil structure formed during freezing. So-called post-cryogenic structure is the structure of thawed soil affected by freezing and thawing. Such structure makes soil of the active layer highly permeable especially in horizontal direction. Proper cleanup response to petroleum releases requires a good understanding of how these cryogenic processes will affect petroleum migration through the subsurface. Currently little is known on this subject. Critical questions such as how does pore ice influence the lateral and vertical migration of petroleum, how does soil-water content prior to freezing influence the migration of petroleum, and how do the physical and chemical properties of petroleum hydrocarbon influence the migration? This study is producing results that help answer these relevant questions.

Problem & Research Objectives

The objective of this research is to gain a better understanding of how the movement of immiscible fluids, specifically petroleum hydrocarbons, through porous media is influenced by seasonal freezing. This objective is being accomplished through laboratory testing and quantitative analysis.

To study contaminant movement in freezing soil it is important to recognize the main patterns of frozen media:

The frozen active layer above unfrozen soil;
The frozen active layer above permafrost;
The unfrozen active layer above permafrost.

Permeability (saturation) of permafrost depends on soil genesis, soil type, and genesis of permafrost (syngenetic or epigenetic). Soil of the same type can be practically unsaturated or even over saturated with ice depending on a genesis of permafrost.

The structure of the active layer is greatly dependent upon the freezing system (open or closed). The active layer over permafrost is usually formed in the closed system. In areas of cold permafrost where soil in the active layer freezes downward from the surface and upward from the bottom of the permafrost table, upper and lower part of the active layer can be saturated with ice and middle part of the active layer is dry and has high open porosity due to vertical and horizontal cracks. In areas of warm permafrost, freezing proceeds only downward from the surface and ice saturated upper part of the active layer is often underlain by dry soil with cracks. Also thickness of saturated soil depends on numerous factors, there are several general patterns in soil structure in the active layer and permafrost which study can provide understanding of permeability of frozen soil. All of these effects influence the lateral and vertical movement of petroleum product that is inadvertently released to frozen soils. We are developing a better understanding of how pore ice influences this movement by using laboratory scale soil flumes performing laboratory studies on the movement of petroleum through frozen soil. Characteristics of petroleum hydrocarbons through unsaturated soils and their fate in the subsurface have been under study for several decades. Many definitive manuscripts have been written that describe the physical and chemical fate of these compounds in soils that do not experience temperatures below zero degrees Celsius. However, little is known about the chemical fate of these compounds in soils that experience seasonal freezing and thawing. Chemical fate in this study is defined as the partitioning between the volatile, dissolved, adsorbed, and liquid fractions in unsaturated soils. The relative fraction of each of these different phases influences the gaseous phase, aqueous phase, and liquid phase migration of petroleum hydrocarbons. A quantitative analysis of phase partitioning in freeze susceptible soils is used in this study to better understand the influence freezing has on the chemical and physical fate of petroleum hydrocarbons in soil.

Methodology

The laboratory flumes used for this study were designed and constructed after extensive literature review on the topic of immiscible fluid migration in soils (Figure 1). Two flumes were constructed. To investigate how pore ice impacts the migration of petroleum hydrocarbons the flume will be filled and compacted with sand wetted to uniform water content and placed in the cold room at a temperature of approximately -5^{o} C. The properties of the sand (water retention characteristics, permeability, porosity, density) are measured in the laboratory. Colored petroleum is introduced into the column. Progression of the resulting immiscible fluid plume is tracked using time-lapse photography. Several initial water contents (prior to freezing) are been investigated.

Figure 1. Soil flumes for frozen ground study

Principal Findings to Date and Significance

Several migration tests have been conducted. Two of these tests are reported here. The two tests differed in water content, with one test having roughly twice the water content as the other. Colored petroleum (100 ml) was introduced into the frozen sand in each flume. The progression of the petroleum was monitored over time. Figures 2 shows the resulting plumes at approximately 18.5 hours.

Figure 2. Plume shapes after approximately 18.5 hours for two flumes. The flume on the right has twice the water content prior to freezing as the plume on the left.

In Figure 2, note the increased lateral spread of petroleum in the flume containing the higher water content (flume on the right side of the figure). The increased capillary forces due to the increased pore ice are evident in this flume in comparison to the plume shape in the flume with half the initial water content. Field studies also show the influence of increased capillary forces due to pore ice. A manuscript detailing this field study has been accepted for publication in the Journal *Polar Record*. Future laboratory tests will include conducting similar tests with a different gradation of sand.

So far laboratory tests and field studies designed to allow us to gain a better understanding of the mechanisms that control plume migration into a frozen sand have been discussed. Once petroleum hydrocarbon has been introduced into soil, the chemical and physical fate of the contaminant during cyclic freeze thaw processes is also of interest. Past documented laboratory measurements have shown movement of petroleum hydrocarbons to the freezing front in contaminated freezing soils. The mechanisms that are, in part, responsible for the increased contaminant concentration at the freezing front are illustrated in this study with a mass balance model. Results developed in this study show that this concentration increase is due to exclusion of petroleum hydrocarbon from the crystalline ice structure and from physical displacement of liquid petroleum hydrocarbon from the pore space as water freezes and expands into ice. A manuscript discussing this model and the results has been submitted to *Polar Record* for peer review.

Hydrological and Geomorphological Controls on Sediment Transport Processes in the Alaskan Arctic

Basic Information

Title:	Hydrological and Geomorphological Controls on Sediment Transport Processes in the Alaskan Arctic
Project Number:	2002AK2B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, Geomorphological Processes
Descriptors:	
Principal Investigators:	Larry D. Hinzman

Publication

1. Oatley, J.A. 2002. Masters thesis: Ice, bedload transport, and channel morphology on the Upper Kuparuk River, University of Alaska Fairbanks, 92 pp.
2. J. A. Oatley, L. D. Hinzman, D. L. Kane and J. P. McNamara. 2003. Case study of a large summer flood on the North Slope of Alaska: bedload transport. Proceedings 14th Northern Research Basins Symposium and workshop. Kangerlussuaq, Greenland. In Press.
3. J. A. Oatley, L. D. Hinzman, D. L. Kane and J. P. McNamara. In Prep. Suppression of bedload transport by bedfast ice. Geomorphology.

Problem and Research Objectives

The objective of this research is to develop a better understanding of watershed morphology and to elucidate how a basin structure may evolve with the onset of climatic warming. Over the past several years, river morphology studies performed in the Kuparuk River have documented some of the changes that have occurred as a result of bedload transport. This study will provide insight into the nature of the bedload transport process. The study is being conducted in the upper Kuparuk River, near the intersection of the river and the Dalton Highway.

Objective

There are three primary goals for this study:

1) Use predictive methods to determine the total sediment load in the river for a given flow rate.
2) Compare the bedload material movement that occurs during the spring snowmelt to that which occurs in response to significant rainfall events during the summer.
3) Compare features of three arctic rivers to identify characteristics that may be symptomatic of the role of ice in arctic river morphology.

Methodology

Several field measurement methods have been, and will continue to be used to quantify the total amount of sediment transport.

Suspended sediment is being measured directly by using an auto-sampler to collect 1-liter samples at regular time intervals during the summer months. These samples will be filtered and weighed to determine the mass of solid material in each sample.

Bedload material movement is being monitored by two different methods. One method is tracer rocks; the other method is sediment traps. Scour chains, located throughout the study reach are also being used.

A total of 400 Tracer rocks are being used to study the movement of specific pieces of cobble. Both active and passive tracer rocks have been placed in the channel. The passive tracers are painted rocks. The active tracers are rocks that have a small radio transmitter implanted in them. These transmitters emit a different pulse rate at rest than during movement. This feature allows knowledge incipient motion.

Sediment traps are being used to capture particles (greater than 3mm diameter) during motion. These traps will be fixed to the riverbed and the current will carry particles into the traps.

Principal Findings and Significance

During the summer of 2001 the study reach was fully surveyed and field measurements of the channel material grain size distribution were made in the form of Wohlman pebble counts. This information has been used to perform the modeling task of predicting the bedload rating curve for the study reach. The bedload rating curve analysis showed that the competent flow threshold for this channel is approximately 20 m^3/s. Since this study began the peak flow volume has been 16.4 m^3/s, so there has not been a significant amount of bedload movement to this point. Of the 201 tracers that were in place during the snowmelt period of 2001, 14 tracers moved a measurable distance and another 12 tracers were not recovered.

During the snowmelt period of 2002 the discharge, channel cross section, and water surface slope were monitored on the Upper Kuparuk River, in the Alaskan Arctic, to determine how the Manning's roughness coefficient varied during this dynamic event.
The results show that at the onset of runoff on May 20th, while the ice was still fresh, the calculated roughness value of 0.025 was similar to that of a sand-bed stream. As the ice began to erode and large blocks of ice broke free and became entrained in the flow, the roughness value increased to a maximum value 0.051. This maximum value corresponded in time with the peak discharge value on May 24th. Over the next week, as considerable ice remained in the channel, but less was entrained in the flow, the discharge dropped to a baseflow level and the roughness value stayed near 0.040. On June 14th the ice-free Manning's roughness value, during low flow, was calculated to be 0.050.

An August 2002 precipitation event on the Upper Kuparuk River resulted in the largest discharge level (snowmelt or rainfall) over the ten-year period of monitoring at this site. During the second largest runoff event, in July 1999, channel cross section survey data and scour chains were used to study the effects of the flood on reach-scale channel morphology. In addition to channel cross sections and scour chain data, this study incorporated bed material grain size distributions and tracer rocks to monitor bedload transport during snowmelt runoff, as well as during summer rainfall events. All of these methods were utilized to study the bedload transport and morphological impact of the 2002 storm on the study reach of the Upper Kuparuk River research watershed. This flood mobilized virtually the entire bed, with the exception of random boulders greater than 0.5m. The channel cross-section and water edge survey data illustrate the considerable morphologic response generated by the flood. The magnitude of this response resulted in only a 13% tracer rock recovery rate. Using the virtual velocity method the total bedload transport was estimated to be 870 m^3 of bed material.

Arctic rivers differ from those of more moderate climates in that ice is present in the channels for eight or more months a year. Also, due to the continuous permafrost presence, there is little or no baseflow during these winter months and the headwaters and shallow reaches of these river channels freeze solidly to the riverbed. This condition is referred to as bottom ice.

In this region, all precipitation from approximately October through May is stored as snow and then released over a 6-20 day snowmelt runoff period. This snowmelt runoff is often the major hydrologic event of the year, frequently of channel-forming competence. However, in the headwater and shallow reaches of these rivers, where most of the sediment in the river system would originate, the bottom ice armors the riverbed and banks, protecting them from sedimentation processes.

The study of bedload transport initiated with the objective of quantifying the impact of bottom ice on sedimentation processes. The approach taken was to use the Meyer-Peter and Mueller (1948) and Parker (1990) equations to estimate the bedload rating curve, and to apply the rating curve to the ten year flow history of the study site to determine the total potential bedload transport that was suppressed during snowmelt runoff. The results suggest that the potential bedload transport suppressed (500 m^3) over the ten-year flow history is comparable to the amount of transport that occurred during the extreme event of August 2002 (870 m^3), and that the suppression of bedload transport, due to an ice covered bed surface, affects the morphology and sediment supply of the river.

Molecular characterization of organic matter in soil leachates from the Caribou Poker Creeks Watershed

Basic Information

Title:	Molecular characterization of organic matter in soil leachates from the Caribou Poker Creeks Watershed
Project Number:	2002AK4B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Groundwater, Water Supply
Descriptors:	organic geochemistry, pyrolysis-GC/MS, DOC fingerprinting
Principal Investigators:	Daniel M. White, Kenji Yoshikawa

Publication

1. White, D. K. Yoshikawa, and D. Garland, (2002), Fingerprinting dissolved organic matter to support hydrologic investigations, Cold Regions Science and Technology, Vol. 35, pp. 27-33.
2. Vincent Autier (2002), Predicting Contaminant Transport Pathways in the Caribou-Poker Creeks Watersheds. MS. Civil Engineering, Thesis, University of Alaska Fairbanks.
3. Autier, V. D. White, and D. S. Garland, (2002), Seasonal variation of organic matter chemistry in a boreal watershed, 53rd Arctic Science Conference, American Association for the Advancement of Science, Fairbanks, Alaska.

Problem and Research Objectives:

The Caribou and Poker Creek Research Watershed (CPCRW) is an important component of the Bonanza Creek Long Term Ecological Research (LTER) Program. A broad range of research is conducted at the CPCRW, including studies on the interactions between hydrology, ecology, meteorology, and permafrost. Previous studies at the CPCRW attempted to characterize the nature and origin of organic matter in water below or above permafrost, in interpermafrost springs, and in streams (Autier, 2002).

Contaminants are ubiquitous in the Arctic. It is therefore imperative to understand their mobility. Organic matter is believed to serve as a primary carrier of contaminants in Alaskan surface and ground waters. Understanding the origin of organic matter is important for studies of drinking water treatment and use, and its affinity for contaminants.

The primary objective of this project was to obtain and characterize soil leachates from the CPCRW in an attempt to understand contaminant transport in a permafrost-dominated watershed. The hypothesis of this work is that soil leachates from different source vegetation will exhibit different characteristics that can be quantified using pyrolysis-gas chromatography/mass spectrometry (py-GC/MS). If follows that leachates from different areas of the watershed would thereby have different potentials to mobilize contaminants.

Natural organic matter (NOM) in soil leachates from soil cores was collected and subjected to a number of analytical processes, including pyrolysis-GC/MS. This "molecular fingerprinting" analysis was used to help determine similarities and differences in organic matter leached from areas with different cover vegetation. Understanding the characteristics of the organic matter from different soils could help us determine what vegetation types deposit organic matter likely to mobilize contaminants.

Methodology

Site Selection

Soil cores were collected during summer 2002 from 11 sites in the CPCRW with different primary vegetation. Duplicate soil cores were removed from each site. Table 1, below, lists soil core identification and descriptions.

Table 1

Soil Core Identification	Vegetation Description
Haystack Ridge	Sphagnum moss, Dwarf birch, Low bush cranberry, Blueberry, Black spruce
Haystack Ridge 2	Feather moss, Sphagnum moss, Dwarf birch, Low bush cranberry, Blueberry, Black spruce
South Haystack 1	Birch, Feather moss, Cranberries,

(S. Hay 1)	Graminoids**,** White spruce
South Haystack 2 (S. Hay 2)	White spruce, Birch, Grass litter, Little feather moss
Hard wood Lower Boundary (HWLB)	Aspen and birch trees, Sporadic white spruce**,** Feather moss, Labrador tea, Low bush cranberries,
Upper Black Spruce (UBS)	Black spruce, Feather moss, Salix, Low bush cranberry, Very little blueberry, Labrador tea, Dwarf birch, Willow
Lichen Ground	Black spruce, Lichen, Low bush blueberry, Low bush cranberry, Salix, Dwarf birch
Active Pingo	Black spruce, Willow, Wild Rose, Feather moss, Aspen leaf litter, Spruce cones
Pingo 2	Open black spruce, Dwarf birch, Sphagnum moss
Pingo 3	Black spruce, Lichen, boundary between Sphagnum and Feather moss,
Creek Side of Collapsed Pingo (CSCP)	Feather moss, Dwarf birch, Salix, Blueberries, Graminoids

Py-GC/MS of CPCRW water samples

Py-GC/MS was conducted with a CDS Model 2500 pyrolyzer and state of the art autosampler in tandem with a gas chromatograph/mass spectrometer (GC/MS). During pyrolysis the sample was heated from a starting temperature of 25 ^oC to 700 ^oC in 0.1 seconds and held at a constant 700 ^oC for 9.9 seconds. The pyrolysis reactor was mounted on an HP 5890 Series II GC, with a Supelco SPB 35 (35% Ph Me silicon) column, 60 m x 0.25 m x 0.25 µm. The GC interface temperature was set at 235 ^oC. The GC temperature program was 45 ^oC for 5 minutes, 2 ^oC /min to 240 ^oC and held for 25 min. The GC was plumbed directly to an HP 5971A Series Mass Selective Detector on electron impact (EI) mode. The MS scanned mass units 45 to 650. All mass spectra were compared to the NBS54K spectral library. Helium served as a carrier gas at a flow rate of 0.5 cm^3/minute. Each sample was injected with a split ratio of 1:50.

Sample preparation and py-GC/MS of soil leachates

To obtain the soil leachate, each core was mixed with 7.5L of water treated by reverse osmosis. The soil was sieved to break down aggregates and homogenize the solution. The soil-water solution was stirred and left soaking overnight. All leachable organics were removed from the solution and were dried under vacuum at 40 ^{o}F to prevent loss of organic matter to volatilization. The solids remaining from the drying procedure were collected and subjected to fingerprinting analysis using a py-GC/MS. Samples were subjected to the same py-GC/MS procedure as CPCRW waters except the temperature program was 40 ^{o}C held for 30 minutes, 1 ^{o}C/min for 80 min, 20 ^{o}C/min for 50 minutes and 10 ^{o}C/min for 10 minutes and held for 10 minutes.

Principal findings and significance

The fingerprinting technique provided us with generalizations and specifics about the chemical make-up of leachable organics. As in White and Beyer (1999), we expected that different soil leachates would be correlated if the cover vegetations were different. We also expected that soil leachates would be uncorrelated if the cover vegetation was different.

Strongest Positive Correlations

The strongest correlation was defined as those correlations with an "r" greater than 0.95; 9 such correlations existed (see Table 2). Results suggested that those soil cores with common vegetation appeared to be most strongly correlated. Among the strongest correlated were the samples collected from areas containing spruce trees. Both black spruce and white spruce are common in CPCRW. Additionally, common vegetation, among some or all of the 9 strongest correlated samples, was sphagnum moss or feather moss (see Figure 1). The distinction between moss covers was not shown in the correlations.

Weakest Positive Correlations

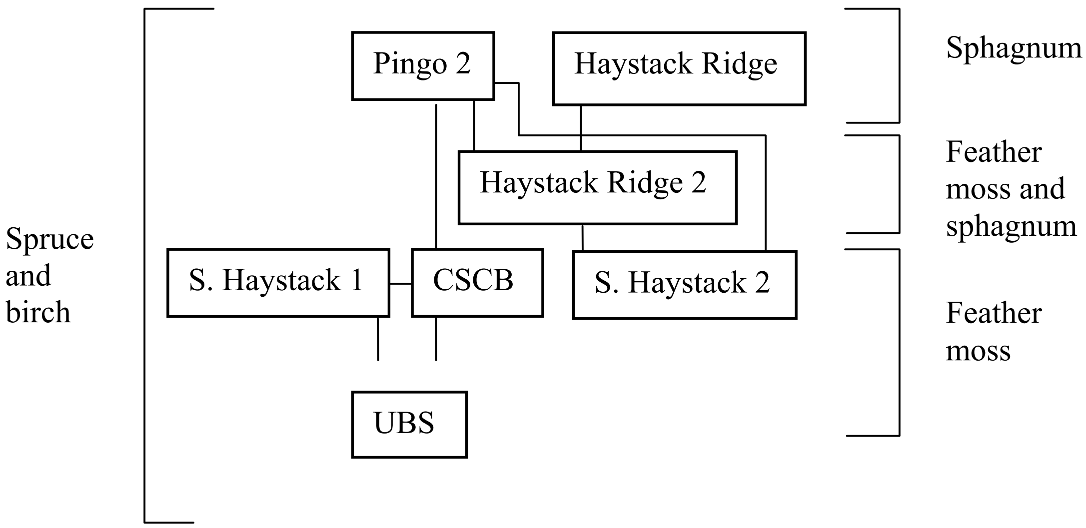
As expected, preliminary results indicated that those cores with dissimilarities in vegetation appeared to be uncorrelated. Those soil cores with r < 0.50 were considered uncorrelated. Five combinations resulted in a correlation less than 0.50 (see Table 2). The primary explanation for this appeared to be the presence or absence of aspen trees in the contributing to soil litter. The hardwood lower boundary sample, for instance, contained aspen, birch, and spruce trees. This core was correlated below 0.50 with five of the ten cores even though sporadic spruce were present at the HWLB.

Table 2. Correlations among Soil Cores

	Active Pingo	Haystack 2	Haystack Ridge	HWLB	Lichen Ground	Pingo 2	Pingo 3	CSCP	S Hay 1	S Hay 2
Haystack Ridge 2	**									
Haystack Ridge	*	0.97								
HWLB	0.28	*	*							
Lichen Ground	*	**	**	0.49						
Pingo 2	*	0.98	***	*	**					
Pingo 3	*	**	**	0.42	***	**				
CSCP	*	**	**	0.48	***	0.97	**			
S Hay 1	*	**	**	*	**	**	**	0.96		
S Hay 2	**	0.98	**	*	**	0.96	**	**	**	
UBS	*	**	**	0.42	**	**	**	0.97	0.96	**

*r = 51-75, ** r = 76-95

(a)



(b)

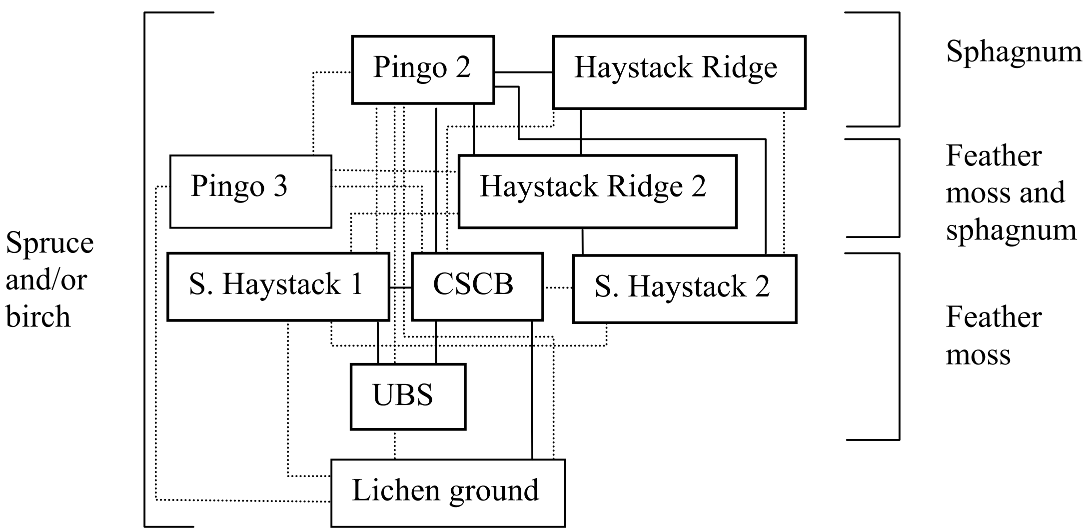


Figure 2. Correlation between leachates from different samples. The solid lines represent correlations r>0.95 (a), dotted lines represent correlations with r>0.89 (b).

Conclusions of work to date

Preliminary results suggest that the chemical make-up of organic matter in leachate from soil under different dominant vegetation types was statistically different. In particular, samples containing birch and spruce were well correlated, even if the groundcover was different. On the other hand, the presence of aspen trees at a site caused the leachate to be statistically different even if spruce trees were present. Other factors, such as the moisture content of the soil, incident sunlight, and soil depth will be considered as factors affecting soil leachate chemistry.

Additional effort will focus on studying the chemical differences between these sites. Knowing the basic chemical make-up of different soil leachates improves our ability to protect infiltration areas most susceptible to contaminants.

References

White, D.M. and Beyer, L., (1999) "Pyrolysis-GC/MS and GC/FID of three Antarctic soils", *Journal of Analytical and Applied Pyrolysis*, Vol. 50, pp. 63-76.

Vincent Autier (2002), "Predicting Contaminant Transport Pathways in the Caribou-Poker Creeks Watersheds." MS. Civil Engineering, Thesis, University of Alaska Fairbanks.

Investigation of Fouling in Membrane Bioreactors for Wastewater Treatment

Basic Information

Title:	Investigation of Fouling in Membrane Bioreactors for Wastewater Treatment
Project Number:	2002AK5B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Water Quality
Focus Category:	Waste Water, None, None
Descriptors:	fouling, membrane bioreactors, wastewater
Principal Investigators:	Silke Schiewer

Publication

1. Psoch, C.; Schiewer, S.: Air sparging in membrane bioreactors to enhance permeate flux and aeration. In: Proceedings of the 5th International Membrane Science and Technology Conference (IMSTEC), Sydney, 2003, (submitted)
2. Psoch, C.; Schiewer, S.: Fouling reduction by air sparging in synthetic wastewater filtration. 14th annual meeting, North American Membrane Society (NAMS), Jackson Hole, 2003 (oral presentation, poster and abstract).
3. Psoch, C.; Schiewer, S.: Air sparging in membrane bioreactors for oxygenation in wastewater treatment. 14th annual meeting, North American Membrane Society (NAMS), Jackson Hole, 2003 (oral presentation, poster and abstract).
4. Psoch, C.; Schiewer, S.: Strategies for enhanced performance of wastewater treatment in membrane bioreactors. In: Proceedings of ASCE/EWRI World Water & Environmental Resources Congress, Philadelphia, 2003.

Problem and research objectives

Alaska's ecosystems are sensitive to disturbances such as water pollution. Due to the cold temperatures, organic pollutants still present in the discharged wastewater are degraded at a much slower pace than in warmer climates. Therefore, especially in protected areas or ecosystems already exposed to heavier pollution, the amount of pollutants discharged into surface waters has to be limited. Membrane bioreactors, with which a very high effluent quality can be achieved, can contribute to reduce aquatic pollution.

While the use of membrane bioreactors in wastewater treatment is rapidly growing worldwide, this relatively new technique faces the problem of membrane fouling which is the main drawback of this process. Therefore it is necessary to undertake further investigations with the aim of reducing the problem of fouling in membrane bioreactors.

The goal of the proposed project is to provide knowledge that can help to reduce fouling in membrane bioreactors. The objectives were to

1. Design and construct a testing facility for an experimental study of fouling in membrane bioreactors, using synthetic wastewater.
2. Experimentally test methods to reduce fouling and investigate the effect of operating parameters on permeate flux and fouling, using this testing facility.

Methodology

The chosen method for fouling reduction was air sparging. . Gas sparging, i.e. injecting of air into the feed of the membrane to generate a gas liquid two phase cross flow, which induces a higher shear stress on the membrane surface, helps to fight the build up of a cake layer, thereby maintaining a stable permeate flux over longer time-periods.

For the bioreactor, an activated sludge tank with 80 liter was used. The synthetic wastewater and activated sludge were pumped with a submerged pump (Grundfos) to the external membrane module.

The polymer membrane (PCI) has a length of 1.20 m and a pore size of 0.2 µm. The module is made of five tubes each with an inner diameter of 6 mm, yielding a membrane surface area of 0.1 m^2. On each side of the module, the membrane tubes were extended through an acrylic rod. The acrylic extensions with drill holes in the same diameter as the membrane tubes served for the air supply and for observation of the flow pattern in the unit. Each tube features its own connection to the air supply, with separately adjustable air volume stream for the air sparging.

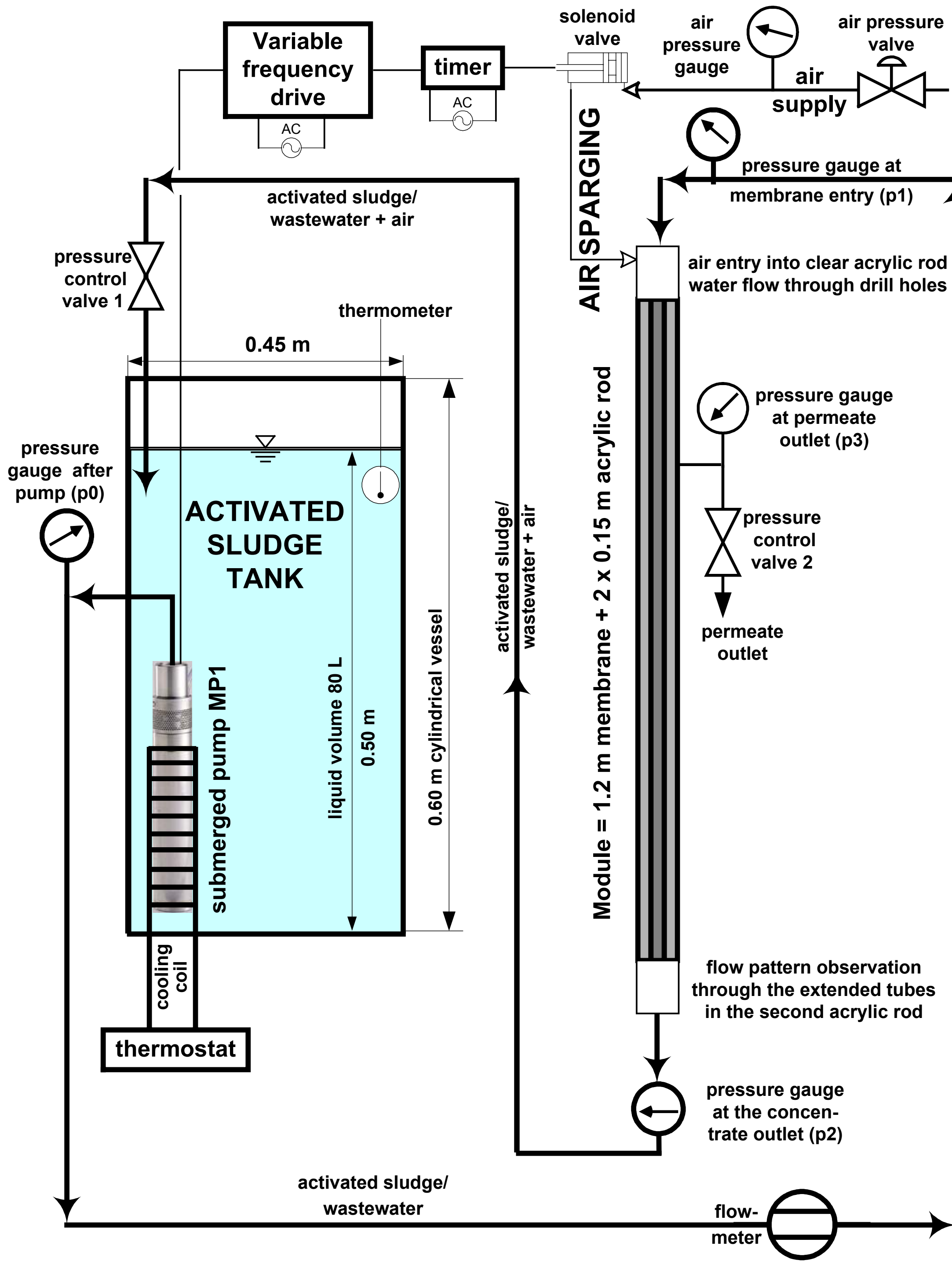


Figure 1. Scheme of the experimental setup

Principal findings and significance

The first set of experiments was performed with a synthetic wastewater based on dry milk powder. Milk in context with aeration shows a high tendency to build up fine foam. Thus, it was essential to add antifoam agents.

The influence of air sparging on wastewater filtration through membranes was investigated by comparing the flux in conventional operation to air sparged operation . The inclination of the membrane and the flow direction of air and water were varied as parameters. Three different setups have been investigated:

- upward vertical
- upward 45° inclined
- downward 45° inclined

For the wastewater filtration and for clear water a more stable flux with less decrease compared to the initial value could generally be observed when air sparging was applied, however the observed effect in maintaining the flux rate was not as pronounced as reported in the literature. Downward flow at a 45 ° inclination lead to a worse flux decline than straight or inclined upward flow, indicating that one of the latter configurations should be used. For further experiments, it was chosen to use vertical upward flow since it is more relevant for full scale applications.

To avoid problems related to foam production and side effects of antifoam substances, the second set of experiments was performed with a wastewater that contained glucose as the primary substrate. The reactor was first operated for a period of 11 days without air sparging, using a conventional aeration to supply oxygen to the bioreactor. A steady flux decline was noted for the first nine days, after which the flux stabilized reached a more stable value. On the 12th day air sparging was applied. Air sparging immediately yielded an increase in permeate flux. A higher flux was maintained in the following weeks even though the mixed liquor suspended solids concentration increased, which could potentially lead to increased fouling. Transmembrane pressure and temperature were maintained stable within a narrow range, so that the effect of these parameters was minimized. Gradual increase of the gas velocity showed that the highest flux rates were achieved when the superficial gas velocity approached the superficial liquid velocity. Thereby the permeate flux could be increased from about 3 L/m^{2}h without air sparging to almost 6 L/m^{2}h with air sparging.

An additional aspect of this set of experiments was to investigate to what extent air sparging could supplement or replace conventional aeration as a means of providing the necessary oxygen for the bioreactor. Comparing the oxygen saturation using only conventional aeration to the oxygen saturation using only air sparging yielded that a higher oxygen saturation could be achieved with air sparging even though a much lower air flow rate was used. One reason for this is the increased air contact time in the membrane loop. The results show that air sparging can serve a dual purpose of fouling reduction and oxygen supply, eliminating the need for conventional aeration of the bioreactor, which could lead to cost savings in industrial operation.

Chemical analysis of feed and permeate for standard wastewater parameters (COD, nitrogen compounds, phosphate) yielded that the bioreactor was effective in treating the wastewater, achieving about 90 % reduction in COD.

Luminescent Bacteria: A New Water Quality Issue?

Basic Information

Title:	Luminescent Bacteria: A New Water Quality Issue?
Project Number:	2002AK7B
Start Date:	3/1/2002
End Date:	2/28/2003
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Principal Investigators:	Joan F. Braddock

Publication

1. Budsberg, K.J., C.F. Wimpee and J.F. Braddock. Isolation and identification of Photobacterium phosphoreum from an unexpected niche: migrating salmon. In Review. Applied and Environmental Microbiology.
2. Budsberg, K.J., C.F. Wimpee and J.F. Braddock. 2003. Phenotypic characterization of Photobacterium phosphoreum from migrating Alaskan salmon. In Abstracts of the 103th General Meeting of the American Society for Microbiology, Washington, DC, May 2003.
3. Budsberg, K.J., C.F. Wimpee and J.F. Braddock. 2003. Genomic cloning of the lux operon from luminous Alaskan isolates. Oral presentation at the Alaska Chapter of the American Society for Microbiology 19th Annual Meeting, Anchorage, AK, April 2003.
4. Budsberg, K.J., C.F. Wimpee and J.F. Braddock. 2002. Isolation and identification of Photobacterium phosphoreum from a new niche: Yukon River salmon, Alaska, USA. In Abstracts of the 102th General Meeting of the American Society for Microbiology, Salt Lake City, UT, May 2002, p. 248.

Problem and Research Objectives

The overall objective of this study is to characterize luminescent bacteria isolated from salmon harvested for subsistence use on the Yukon River. Subsistence fishers from several native villages on the Yukon River reported fish in fall 2001 on fish racks “glowing in the dark” This caused substantial alarm in the rural community as an important and traditional food source appeared to be tainted. It is not clear why this phenomenon has not been more widespread in other years, although fishers on the Yukon River have noted limited occurrences for a number of years (Randy Brown, U.S. Fish and Wildlife Service, personal communication). It is also not known how commonly luminescent bacteria are found on salmon returning to spawn from the marine environment. Furthermore, until this study, it was not known exactly what species of bacteria were responsible for the outbreak seen in 2001.

It is important to understand that no known luminescent bacteria are pathogenic but several species are closely related to known human and fish pathogens (e.g., several strains of *Vibrio cholerae* and *V. vulnificus* are bioluminescent). In addition, the presence of luminescent bacteria on fish in the cold smoke processes has been used as an indicator of spoilage. Our preliminary data indicated that luminescent isolates from Alaskan salmon may be different from other known luminescent bacteria. Thus to assure the safety of fish on which these bacteria are growing, the identity of the bacteria was very important to determine.

Subsistence fishers on the Yukon River have observed “glowing” fish in other years (Randy Brown, U.S. Fish and Wildlife Service, personal communication), but the phenomenon was widespread in fall 2001. It is known that luminescent bacteria “light up” only upon reaching a high population density; apparently conditions favored growth of these bacteria in summer 2001. The presence of luminescence on Yukon River salmon led to a number of interesting questions: (1) What taxonomic groups do our bacterial isolates belong to? (2) Are the Alaskan isolates taxonomically different from other previously described luminescent bacteria? (3) How are the bacteria transported to the freshwater environment? Via the fish gut or slime layer or other parts of the fish? (4) Are other species of luminescent bacteria present in fish traveling up Alaskan rivers to spawn? (5) Can planktonic luminescent bacteria be found in the Yukon River? (6) Assuming our isolates are of marine origin, do the bacteria possess physiological adaptations that allow them to survive in the freshwater habitat? (7) Were conditions unique in summer 2001 that allowed more widespread occurrence of luminescence on fish? (8) Are the isolate from 1997 and the isolates from 2001 the same organism? (9) Are isolates found in different locations on a single fish the same organism? (10) Is the occurrence of “glowing fish” likely to be high in the future due to other factors such as global change or the overall health of the fish? The first year of this project focused on answering questions (1), (2), (4), (6) and (8).

Approaches and Methodology:

To characterize our isolates first extensive phenotypic analyses were performed (as described in Reichelt and Baumann, 1973; Nealson, 1978). Second, characterization of the *luxA* genes were performed as previously described (Wimpee et al., 1991). Briefly, genomic DNA was isolated, *luxA* primers were used in PCR amplification, amplified fragments were cloned into pCRII-TOPO (Invitrogen Corp.), and the resultant cloned DNA was sequenced on an automated sequencer. The sequences were subjected to phylogenetic analysis using programs in the PAUP package (Swofford, 1998). Thirdly, a similar strategy was used for the 16S rRNA gene. Universal bacterial primers ("11F " and "1492R") were used to amplify 16S, followed by cloning, sequencing, and phylogenetic analysis. Finally, in addition to the sequence analysis of *luxA* and 16S, a genomic library was constructed, and the cloned *luxA* gene was used as a probe to isolate the entire *lux* operon from our Alaskan strains.

Principle Findings and Significance:

All our Alaskan isolates are short rods, oxidase negative, Gram negative, and require L-methionine for growth in minimal media. Additionally, all Alaskan isolates grow at 4° C, however, optimal growth occurred at 10 - 15° C; no growth occurred at or above 20° C. Growth required the presence of sodium chloride in the medium and cells did not remain viable in river water unless amended with sodium chloride. Comparing our nutritional versatility data to published references, we can place all Alaska strains in the *P. phosphoreum* group. To verify our results, a reference strain, *P. phosphoreum* NZ-11-D, was included in the test (Table 1). The ability of NZ-11-D to utilize acetate and AK-3 to utilize pyruvate do not present any difficulty in placing Alaskan strains in the *P. phosphoreum* group because of the genetic information described below.

SSU rDNA gene sequences of the seven AK isolates were aligned with six representative sequences from other luminous bacteria. The alignment produced a consensus sequence 1,159 bp in length shared by all 13 taxa. Maximum likelihood analysis of the alignment by PAUP v4.0 revealed all AK isolates cluster identically with *P. phosphoreum* (Figure 1). *E. coli* was used as the outgroup in the maximum likelihood analysis of the SSU rDNA genes.

luxA (a gene necessary for luminescence in all luminescent bacteria) sequences of the seven AK isolates were aligned with six representative sequences from other luminous bacteria. The alignment produced a consensus sequence 554 bp in length shared by all 13 taxa. Maximum likelihood analysis of the alignment by PAUP v4.0 revealed all AK isolates cluster closely with *P. phosphoreum* (Figure 2). *V. harveyi luxB* was used as the outgroup in the maximum likelihood analysis of the *luxA* genes.

Our Alaskan strains of *P. phosphoreum* are nearly identical to other descriptions with respect to nutritional versatility, *luxA* and SSU rDNA sequences; however, our isolates appear to have a lower optimal growth temperature as compared to the reference strain, *P. phosphoreum* NZ-11-D. Future investigations of the osmotic requirements and temperature tolerances of Alaskan *P. phosphoreum* may reveal adaptations specific to this unique niche. In year two of the study we will continue the genetic analyses of our isolates and begin to address ecological questions related to where the bacteria are located on migrating salmon and how prevalent the occurrence is of luminous bacteria on migrating salmon.

References

Nealson, K.H. 1978. Isolation, identification and manipulation of luminous bacteria. Methods Enzym. 57: 153-156.

Reichelt, J.L. and P. Baumann. 1973. Taxonomy of the marine, luminous bacteria. Arch. Mikrobiol. 94: 283-330.

Swofford, D.L. 1998. Phylogenetic Analysis Using Parsimony. Version 4.0.

Wimpee, C.F., T.-L. Nadeau and K.H. Nealson. 1991. Development of species-specific hybridization probes for marine luminous bacteria by using in vitro DNA amplification. Appl. Environ. Microbiol. 57: 1319-1324.

Table 1. Phenotypic characteristics of our isolates.

	Published Reference Data					Tested Strains						
	V. harveyi [a]	*V. fischeri* [a]	*P. leiognathi* [a]	*P. phosphoreum* [a,b]	*P. phosphoreum* NZ-11-D[c]	NZ-11-D	AK-1	AK-5	AK-6	AK-7	AK-8	AK-9
Growth on:												
Maltose (0.2%)	+	+	-	+	+	+	+	+	+	+	+	+
Cellobiose (0.2%)	+	+	-	-	-	-	-	-	-	-	-	-
Glucuronate (0.1%)	+	-	-	(+)	(+)	+	-	-	-	-	-	-
Mannitol (0.1%)	+	+	-	-	(-)	-	-	-	-	-	-	-
Proline (0.1%)	+	+	+	(-)	(-)	-	-	-	-	-	-	-
Lactate (0.2%)	+	-	+	(-)	-	-	-	-	-	-	-	-
Pyruvate (0.1%)	+	-	+	-	-	-	-	-	-	-	-	-
Acetate (0.05%)	+	-	+	-	-	-	-	-	-	-	-	-
Propionate (0.05%)	+	-	-	-	-	-	-	-	-	-	-	-
Heptanoate (0.05%)	+	-	-	-	-	-	-	-	-	-	-	-
D-α-Alanine(0.05%)	+	(-)	-	-	-	-	-	-	-	-	-	-
L-tyrosine (0.4%)	+	-	-	-	-	-	-	-	-	-	-	-
Production of:												
Lipase	+	-	-	-	-	-	-	-	-	-	-	-
Gelatinase	+	-	-	-	-	-	-	-	-	-	-	-
Amylase	+	-	-	-	-	-	-	-	-	-	-	-
Optimal growth temperature:					20° C	22° C	15° C	15° C	15° C	15° C	15° C	15° C

Parantheses in the published reference data indicates strain variability. Tested strains are isolates from Alaskan salmon. [a]Taxonomic information from Nealson (1978), [b]Bergey's Manual of Diagnostic Bacteriology (1994), and [c]Nealson (1993).

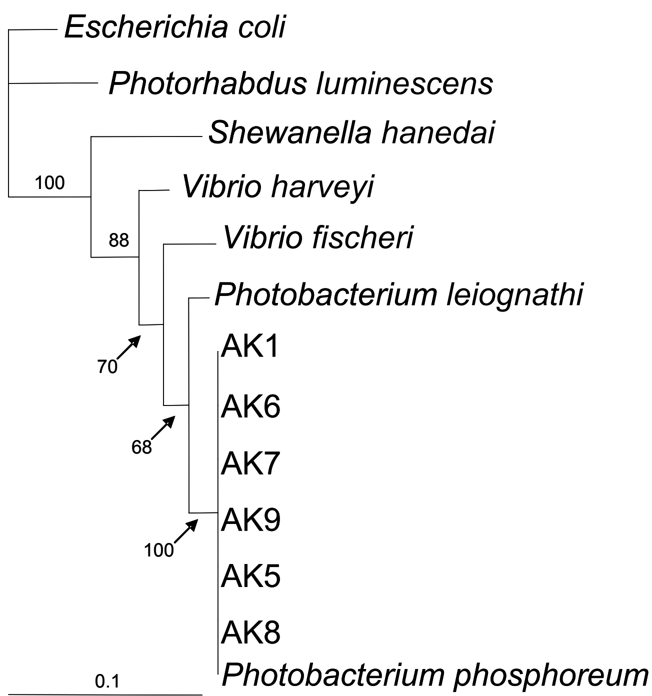

Fig. 1. Phylogeny of Alaskan luminous bacteria based on Maximum Likelihood analysis using PAUP* 4.0b10 with SSU rDNA sequences from Alaskan isolates and representative sequences from GenBank. All strains with "AK" are from salmon harvested from the Yukon River, Alaska. *E. coli* was used as the outgroup in this analysis.

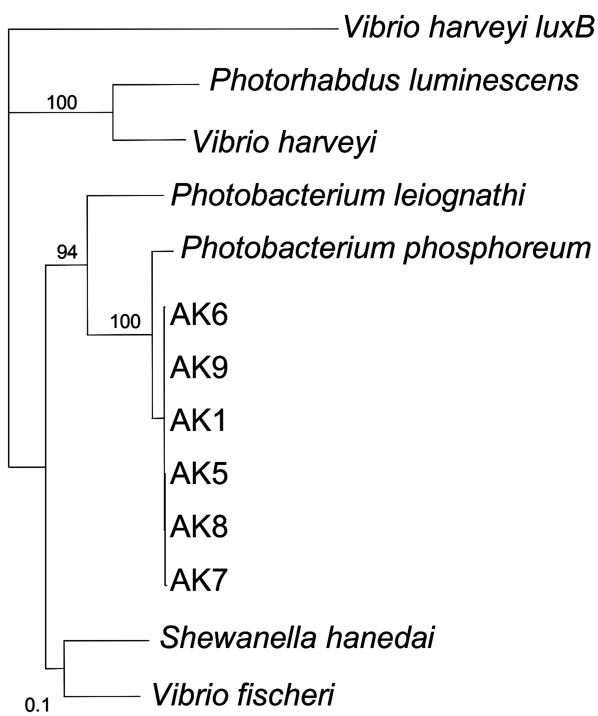

Fig. 2. Phylogeny of Alaskan luminous bacteria based on Maximum Liklihood analysis using PAUP* 4.0b10 with *luxA* sequences. All strains with "AK" are from salmon harvested from the Yukon River, Alaska. *V. harveyi luxB* was used as the outgroup in the Maximum Likelihood analysis of *luxA* genes.

Information Transfer Program

None.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	4	0	0	0	4
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	5	0	0	0	5

Notable Awards and Achievements

None to report.

Publications from Prior Projects