ASSESSMENT OF CONTAMINANT CONCENTRATIONS AND TRANSPORT PATHWAYS IN RURAL ALASKA COMMUNITIES' SOLID WASTE AND WASTEWATER SITES

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ASSESSMENT OF CONTAMINANT CONCENTRATIONS AND TRANSPORT PATHWAYS IN RURAL ALASKA COMMUNITIES' SOLID WASTE AND WASTEWATER SITES

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Abstract

Waste management practices currently employed in many rural Alaska communities are potentially contributing to human and environmental health impacts, and this problem may be exacerbated with the anticipated warming climate. For rural communities, factors that contribute to insufficient waste management practices include climate and environmental conditions, limitation of federal and state capital funding for construction, and the continuing financial burden associated with providing adequate operations and maintenance. As a response, federal regulatory exemptions are granted for construction and design of solid waste sites and limited state regulations are in place for wastewater discharge criteria. Due to the absence of proper site assessment and monitoring, very little is known about the fate and transport of point source pollutants arising from these wastewater and solid waste sites. Moreover, these fate and transport processes may be susceptible to changes resulting from human activity or a warming climate. Thus, this knowledge gap associated with waste-related pollutants in rural Alaska could obscure potential threats to human and environmental health by concealing impacts to freshwater systems.

This research was intended to achieve a better understanding of rural Alaska waste leachate compositions by evaluating contaminant prevalence and diversity, quantifying contaminant concentration levels, and evaluating their potential migration into nearby freshwater systems. Over the course of three years, waste sites at five rural Alaska communities were sampled and tested for heavy metals, organic constituents, and microbial indicator organisms. The purpose of the analysis was to evaluate the impact of waste sites on soil, surface, and subsurface waters in the vicinity of the sites. The resulting findings are assembled into three chapters describing 1) the assessment of heavy metal leachate in rural Alaska solid waste sites, 2) the identification of new emerging organic pollutants in rural Alaska waste sites, and 3) the partitioning and transport behavior of pathogen indicator organisms in cold regions. The research outcome of *E.coli* and *Enterococcus sp.* were observed in waste impacted water and soil samples, heavy metal migration into nearby freshwaters, and pharmaceuticals, phthalates, and benzotriazole in waste impacted water samples. The research findings highlight the need to apply state regulations to remove potentially hazardous components from rural Alaska wastewater and municipal solid waste streams. Additionally, there is a need to establish effective solid waste and wastewater leachate monitoring and assessment strategies for active and closed rural Alaska waste sites.

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List of Abbreviations/Acronyms

AAC	Alaska Administrative Code
ACD CIS	Alaska Community Database Community Information Summaries
ACIA	Arctic Climate Impact Assessment
ADEC	Alaska Department of Environmental Conservation
ADNR Welts	Alaska Department of Natural Resources Historical Welt Search
AEHA	U.S. Army Environmental Hygiene Agency
ANTHC	Alaska Native Tribal Health Consortium
ANOVA	Analysis of Variance
ASET	UAA Applied Science, Engineering, and Technology Laboratory
ATSDR	Agency for Toxic Substances and Disease Registry
BBP	Benzyl butyl phthalate
bgs	below ground surface
BIA	Bureau of Indian Education
BT	1 H-Benzotriazole
CCTHITA	Central Council of Tlingit and Haida Indian Tribes of Alaska
CDC	Center of Disease Control
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CEPA	Canadian Environmental Protection Agency
CWA	Clean Water Act
DBP	Di-n-butyl phthalate
DEP	Diethyl phthalate
DEHP	Diethylhexyl phthalate
DHUD	U.S. Deparment of Housing and Urban Development
DMP	Dimethyl Phthalate
DNOP	Di-n-octyl phthalate
E.coli	*Escherichia coli*
EC	Electrical Conductivity
ECETOC	European Center for Ecotoxicology and Toxicology of Chemicals
EF	Enrichment Factors
ENT	*Enterococcus sp.*
EPA	U.S. Environmental Protection Agency
EPSCoR	Experimental Program to Stimulate Competitive Research
EPA RARE	Environmental Protection Agency Regional Applied Research Effort
FC	Fecal Coliform
gm/kg	grams per kilogram
HDPE	High-Density Polyethylene
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
IGAP	Indian Environmental General Assistance Program
LOD	Limit of Detection
LOQ	Limit of Qanitification
MCL	Maximum Contaminant Level
MDL	Method of Detection Limit
mg/l	milligrams per liter
mm	millimeter
MIO	Microbial Indicator Organisms

MPN	Most Probable Number
MSWLF	Municipal Solid Waste Landfills
N/D	Not Detected
NPDWR	National Primary Drinking Water Regulations
NSDWR	National Secondary Drinking Water Regulations
ORD	Office of Research and Development
ORP	oxidation reduction potential
ppm	parts per million
ppb	parts per billion
PVC	Polyvinyl Chloride
RARE	Regional Applied Research Effort
RCRA	Resource and Conservation and Recovery Act
RPM	Revolutions per Minute
RPP	Rigid Porous Polyethylene
RurAL CAP	Rural Alaskan Community Action Program
TASWER	Tribal Association for Solid Waste and Emergency Response
TOC	Total Organic Carbon
TSS	Total Suspended Solids
4-5 TT	4&5 Methylbenzotriazole
UAA	University of Alaska at Anchorage
UAF	University of Alaska at Fairbanks
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USFDA	U.S. Food and Drug Administration
µg/l	micrograms per liter
WELTS	Well Log Tracking System
WERC	UAF Water and Environmental Research Center
WMP	Waste Management Practice
WWTS	Waste Water Treatment System
XOC	Xenobiotic Organic Compounds

Preface

This research was leveraged with a parallel study intended to assess landfill leachate impacts on rural Alaska drinking water resources conducted by the Environmental Protection Agency Regional Applied Research Effort (EPA RARE) and the Rural Alaska Community Action Program (RurAL Cap). The collaboration of federal, Universities of Alaska Fairbanks (UAF) and Anchorage (UAA) campuses, and tribal environmental representatives was indispensable for data collection, promotion of successful field work, and obtaining local knowledge about the study area. Assistance from local communities was important in assisting with sampling activities, accommodation and transportation. The collaborative project intended to develop better procedures for more effective operation, maintenance and/or closure of current waste disposal sites. The information provided by the parallel study used in this dissertation includes site evaluation, well log reports, location maps, inorganic constituents obtained from shallow groundwater wells, and microbial indicator organisms' density load data.

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Chapter I

1. General Introduction

1.1.1 Waste Management Practice Issues

In the United States, solid waste and wastewater management practices are guided primarily by the Resource and Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Waste management is defined as the distinct practice of collection, transport, disposal, management and monitoring of waste material produced by human activity to prevent any adverse effects for future human and environmental health (LaGrega et al., 1994). Generally, wastewater and solid waste generated by human activity are classified into three groups i) solid waste, ii) liquid waste and iii) gaseous waste (Freeman and Lounsburg, 1990). The environmental regulations require waste management practices to mediate hazardous liquid, solid and gaseous waste material (LaGrega et al., 1994), and focuses on designs and processes for treating, minimizing, remediating and disposing of waste material (Watts, 1997). Factors considered for potential waste facilities include haul distance, location restrictions, available land area, site access, soil conditions, topography, climatological conditions, surface water hydrology, hydrogeological conditions, local environmental conditions, long-term disposal and end use after site closure (Tchobanoglous et al., 2003). Poorly designed waste facilities can often produce leaking liquids, termed leachate. The most common way in which waste leachate affects the surrounding environment is through migration into the nearby surface and ground waters.

Specific federal and state regulations are emplaced for landfill technology and construction based upon the volume and makeup of the waste material. The types of regulated waste include industrial waste, nonhazardous municipal waste and hazardous waste (Fetter, 1999). As hazardous wastes are generally the most difficult and/or expensive to manage, solid waste practices are developed to minimize the volume of hazardous waste in a waste stream. Such processes include waste segregation, reuse, recycling and modification (Freeman and Lounsburg, 1990; Watts, 1997). Solid waste leachate results from precipitation that has infiltrated and percolated through the waste material, then been subjected to physical and chemical transformation processes in the waste itself (Kjeldsen et al., 2002; Tchobanoglous et al., 2003).

The waste leachate concentration is dependent on several factors including waste constituents, waste age and density, treatment and disposal technology, amount of precipitation, groundwater and surface water infiltration, moisture content and surface flow patterns, gas production, and climatic conditions such as evapotranspiration (Åkesson and Nilsson, 1997; Chu et al., 1994; Sundsbak, 1971; Tchobanoglous et al., 2003).

Wastewater treatment systems are constructed to treat domestic, industrial or municipal wastewater sources generated by storm runoff, bathroom, laundry, and kitchen facilities (Eriksson et al., 2002; Imhof and Muehlemann, 2005; NSWHealth, 2000). Wastewater management practices are established for design and operation of centralized or decentralized collection using treatment and disposal technologies to remove chemical and biological pollutants in order to meet required federal and state discharge permit standards (Tchobanoglous et al., 2003). Different levels of wastewater treatment units are available, including primary, secondary and tertiary treatment processes. Such unit processes utilize physical, chemical, and/or biological processes to reduce noxious constituents in wastewater discharge to levels adequate to ensure human and environmental health (Imhof and Muehlemann, 2005; Tchobanoglous et al., 2003). Primary treatment provides physical removal via sedimentation. Advanced primary treatment enhances suspended and dissolved solids removal. Secondary treatment is based on biological and chemical processes for organic matter removal. Tertiary treatment utilizes additional biological, chemical, or physical processes to remove residual suspended solid and hazardous material beyond the secondary treatment level (Tchobanoglous et al., 2003). The concentration of chemical compounds in wastewater treatment effluent is highly influenced by the individual unit processes (Vieno et al., 2005). Wastewater pollution is often associated with poorly operated or designed wastewater treatment systems, system failure, impacts of stormwater and sanitation overflow, municipal wastewater collection system and septic tanks leakage, reuse of wastewater for landscaping and agriculture, and discharge into surface waters, as well as recharge of groundwater (Tchobanoglous et al., 2003). Pollutants emerging from a wastewater treatment plant or contained in solid waste leachate can vary significantly, and are characterized into four pollutant groups: i) heavy metals, ii) dissolved organic matter, iii) inorganic matter, and iv) xenobiotic organic compounds (Kjeldsen et al., 2002; Tchobanoglous et al., 2003).

A robust waste management strategy is needed to ensure human and environmental health. In rural Alaska communities many factors contribute to insufficient collection, transport, treatment,

and disposal of waste material. In order to more fully understand the issues surrounding inadequate waste management practices in rural Alaska, it is necessary to describe the factors contributing to those conditions. The following sections describe 1) the current waste management practices and conditions in rural Alaska communities; 2) the principle concepts of contaminant transport in cold regions; 3) arctic and subarctic environmental conditions that contribute to migration of waste derived pollutants into nearby water resources and environment; 4) the potential impacts of climatic-induced changes to permafrost and precipitation on contaminant transport pathways and mobility; and 5) the human and environmental health impacts associated with waste derived pollutants.

1.1.2 Research Objective

The goal of this study was to evaluate the current state of rural Alaska waste management facilities with respect to the migration of waste-derived contaminants into nearby water resources. This was not intended to be an exhaustive study encompassing all rural Alaska waste sites, but rather an exploratory effort intended to inform future, more comprehensive studies. By identifying typical contaminant composition and concentrations as well as evaluating potential migration pathways into nearby freshwater systems, this work seeks to provide recommendations that will inform management strategies now and in the future. The resulting findings are assembled into three chapters describing 1) the assessment of heavy metal leachate in rural Alaska solid waste sites, 2) the identification of new emerging organic pollutants in rural Alaska waste sites, and 3) the partitioning and transport behavior of pathogen indicator organisms in cold regions.

1.2 Literature Review

1.2.1 Rural Alaska Communities

Alaska is the largest state in the United States with 1,477.000 square kilometers of land, approximately 75,000 square kilometers of glaciated area, more than 12, 000 rivers, more than 3 million lakes, and countless streams, creeks and ponds (Shulski and Wendler, 2007). Alaska is sparsely populated with 710,231 residents, of which 60% are concentrated in or around the Kenai Peninsula, Anchorage, Matanuska-Susitna, Fairbanks, or Juneau areas (Census, Bureau, 2010). The remaining 40% are scattered throughout the state in over 300 rural communities, which are home to approximately 229 federally recognized tribes including Alutiq, Yup'ik, Chup'ik, Sugpiaq, Tlingit, Haida, Eyak, Tsimpsian, Inupiat, and Athabascan. Indeed, Alaska's federally-recognized tribes represent more than 40% of the tribes in the United States (BIA, 2003; Patterson et al., 2012). Most Alaska's rural communities are not connected by road system and are located in diverse geographic areas, ranging from the coasts to the mountains to the open tundra (Olofsson and Schroeder, 1993; Patterson et al., 2012). In addition, Alaska has five distinct climate zones and precipitation patterns: arctic, interior, west central, south central, and maritime (Table 1). Each climate zone is presented with difference in environmental settings such as underlying bedrock, occurrence of permafrost, and fast wetlands. This geographic disparity and Alaska's extreme environmental settings present a unique challenge to waste management practices (Patterson et al., 2012).

Besides climatic and geographical factors, socioeconomic conditions such as small local economies and tax bases, high fuel and shipping prices, short construction seasons, and lack of sufficient local knowledge (i.e. trained personnel and local servicing expertise) contribute to inadequate waste management practices among rural communities (ANTHC, 2007; Duigou, 2006; EPA, 2012). In particular, many communities have limited access to state and federal funding for operation and maintenance of waste facilities (Black and Logan, 2000; Colt et al., 2003; Ritter, 2007). Another common obstacle is the inflexibility of the regulatory review and permitting process. It is reported that the regulatory process is ill-suited to meet the needs of small, remote communities (ANTHC, 2007; Duigou, 2006; Troy, 2007). As a consequence, modern water, sewer, and solid waste disposal services are still lacking in 34% of rural Alaska Native communities (ANTHC, 2007). To establish a more sustainable waste management

practices for rural Alaska communities, Haley (2000) recommended acquiring information from other northern nations about policies, specific practices and system processes.

Improving rural Alaska wastewater management practices is particularly important due to the close proximity of many waste facilities to local water resources or other subsistence areas. To achieve a better understanding of rural Alaska solid waste and wastewater impacts, this research focused on establishing chemical and microbial baseline data to assess the extent and nature of waste derived pollutants, and attempted to evaluate the existing transport pathways between waste facilities and surrounding surface water resources. Identifying and characterizing waste derived pollutants along with their transport pathways is expected to help people in remote northern communities reduce the environmental and human health risk associated with insufficient waste management practices. The research addressed two general questions regarding the status of waste management practices in rural Alaska communities. The first question addresses current environmental impacts of waste derived pollutants and the second question evaluates whether current or future waste disposal practices are sufficient and sustainable to guarantee human and environmental health in light of a changing climate. Rural Alaska communities are especially affected by these climatic changes resulting in more frequent occurrence of flooding and erosion, and permafrost degradation due to rising temperature (GAO, 2003; Jeffries et al., 2013). Considering that 50% of rural Alaska waste disposal facilities are currently underlain by permafrost (Kellems et al., 1991), new regulations and designs for arctic and subarctic waste disposal practices have may be require to address these environmental changes (White, 2008).

1.2.2 Rural Solid Waste Management

The solid waste management program for rural Alaska communities is regulated and implemented under the primacy of Alaska Department of Environmental Conservation (ADEC) through the Alaska Administrative Code (AAC) 18 AAC 60. In Alaska, there are three types of permitted municipal solid waste landfills (MSWLF), including Class I, II, and III. In addition, there are approximately 1,104 unpermitted Class III landfills (EPA, 2008). In response to high construction, operation and maintenance costs of landfills, the State of Alaska specifically designated a Class III landfill category to accommodate rural communities with a population size

less than 500, (Black and Logan, 2000; Colt, 1994; Ritter, 2007). A Class III MSWLF is defined *"as a landfill that is not connected to a Class I MSWLF or, if connected by road is located more than 50 miles from a Class I MSWLF; accepts for disposal, ash from incinerated municipal waste in quantities less than one ton daily on an annual average, or receives less than five tons daily of municipal solid waste, based on an annual average, and is not located in a place where public access is restricted"* (18 AAC 60.300(3)). Federal regulatory exemptions are granted for Class III landfill construction and design. These include construction without a landfill liner, construction without a leachate collection system, minimal capping requirements, and operation without groundwater and methane gas monitoring (EPA, 2008). Consequently, Class III landfills in Alaska are often described as "open dumps". The three most common open dump designs for waste disposal in rural Alaska are: landfills located above ground, landfills contained within trenches, and landfills located in tundra ponds. The three most common landfill designs in rural Alaska are illustrated in Figure I-1.

In rural Alaska most communities have low municipal incomes, and lack the equipment and economic resources to properly manage their solid waste. As a consequence, only a fraction of rural communities dispose of their refuse in permitted landfills (Zender et al., 2003a). The remaining communities dispose their household and hazardous waste material (i.e. cleaning products, antifreeze, lead batteries, electrical waste, etc.) in open dumps. For at least 30% of the communities, human waste is discharged together with solid waste, posing an additional pathogenic risk (Zender et al., 2003a). Historically, these open dumps were operated without site control or routine maintenance, little or no waste separation, and without the knowledge of waste leachate generation and migration in standing water, wetland sites, or seasonal flooding (Patterson et al., 2012). In 2001-2003, the Central Council of Tlingit and Haida Indian Tribes of Alaska (CCTHITA) conducted a statewide evaluation to assess solid waste management conditions and practices of rural Alaska communities. The comprehensive survey of 229 federally recognized Tribes indicated that 60% of communities have access to heavy equipment to consolidate and compact wastes, 32% can afford a part-time operator to manage their solid waste, 6% apply cover material, and in 55% of open dumps, the waste uploading area is already covered with disposed waste (CCTHITA, 2003; Zender and Sebalo, 2001a). In addition, in the near future a large fraction of Alaska communities will face open dump closures that attributed to limited space availability and their close proximity to the communities (ADEC., 2004b.). Although

Alaska appears to have sufficient land available for waste facilities, rural communities experience space limitations caused by complicated land ownership arrangements. The most suitable land available for a landfill is often desirable for housing development or traditional subsistence harvesting areas (Matsuura et al., 2008). Given these circumstances, closing a community's open dump site is an important issue, with 29% of polled communities listing site closure as one of their top waste management concerns (ADEC, 2004b). The conditions and extend of rural Alaska open dumps are illustrated in Figure I-2.

In most rural Alaska communities, almost all of the generated waste is deposited in these open dumps. While a waste generation rate of 5 lbs/person/day is reported for the US as a whole (Smith and Low, 1996), a higher rate of 6 to 7 lbs/person/day is estimated for larger rural Alaska communities (EPA, 2008). Moreover, the waste composition in rural Alaska communities has changed over recent decades from traditional organic materials associated with a subsistence lifestyle to more recalcitrant or hazardous waste products such as antifreeze, gasoline, batteries paints, synthetic packaging material, electronics, construction and demolition debris, personal hygiene products, and pharmaceutical products (Duigou, 2006; Lincoln et al., 2007; Matsuura et al., 2008; Slack et al., 2005; Townsend, 2011; Vrijheid, 2000). Considering the increased generation rate and the change in waste composition, traditional open dumps in rural Alaska present a more severe threat to surrounding water resources than originally thought. In light of this, the ADEC listed approximately 250 rural Alaska landfills as posing a reasonable threat to public and environment health (ADEC, 2004b).

Leachate generated in rural Alaska open dumps is generally not monitored or contained. Thus, the environmental impacts of the leachate are unknown. As many communities dispose their minimally-treated or untreated solid waste directly in tundra ponds or on wet tundra, there is a high probability that waste-generated leachate mobilizes into the surrounding surface or ground waters (EPA, 2009; Patterson et al., 2012). Moreover, arctic and subarctic rural dumps are often subjected to seasonal flooding during the snow melt period, runoff events from warm-season precipitation or thawing of underlying permafrost (Jeffries et al., 2013; Patterson et al., 2012), and illustrated in Figure I-3. These factors can combine to promote the offsite migration of leachate (Patterson et al., 2012). Furthermore, many rural Alaska dumps are constructed above ground, rising up to 3-10 meters above surrounding grade. Thus, this creates a topography that

encourages downslope migration of waste leachate pollutants. Finally, many rural communities have active dumps as well as multiple abandoned dumps located in close proximity to the community and water resources, which can act as additional point sources releasing pollutants (EPA, 2008).

Numerous studies have been performed to evaluate the impacts on surface and groundwater by landfill leachate in temperate climatic regions (Gounaris and Anderson, 1993; Haertling, 1989; Iwegbue et al., 2010; Lunde and Young, 2005; Øygard et al., 2004). However, fewer such studies have been conducted in permafrost regions. One study intended to evaluate cadmium and lead contamination in a Canadian Arctic waste site demonstrated a higher concentration of cadmium in water, while lead concentrations were low due to particulate adsorption (Young and Lund, 2006). A similar study conducted at a Central Arctic municipal waste site in Pangnirung Nunavut, Canada observed trace metal concentrations (Cd, Pb, Cu, Fe, and Zn) in water and sediment samples (Haertling, 1989). In addition, hazardous waste leachate containing high heavy metal concentrations originating from e-waste, batteries, paints, and vehicle maintenance products have been documented in moderate climate region municipal landfills (Ha et al., 2009; Lincoln et al., 2007; Slack et al., 2005; Townsend, 2011; Vrijheid, 2000).

1.2.3 Rural Alaska Sanitation Issues

The major driver in providing sanitation to rural Alaska communities was initiated by the federal Village Safe Water Act, passed in 1970. The Village Safe Water Act set strict chemical and microbiological requirements to ensure clean drinking water for rural residents (Duigou, 2006). In many instances, improving wastewater practices was an essential component of providing safe drinking water. Many rural Alaska communities rely on traditional water resources such as tundra ponds, streams, and rivers for their drinking water. These local water bodies are subject to pollutants resulting from inadequate sanitation practices and therefore, their environmental health has been identified as a critical human health issue (ANTHC, 2009). This situation led to federal and state missions to implement and construct drinking water treatment facilities and wastewater treatment systems as combined projects. The regulatory agencies involved with planning, designing and constructing rural Alaska wastewater treatment systems include the federal Indian Health Service, Army Corps of Engineers, Alaska Native Tribal Health Consortium, and the State

of Alaska Department of Environmental Conservation and Village Safe Water agencies (Herdman, 1994b; Williams, 1993). The sanitation designs and construction methods are proposed by Indian Health Service, Alaska Native Tribal Health Consortium and Village Safe Water. The State of Alaska DEC and Army Corps of Engineers approves the state water quality standards for wastewater discharge permits under the federal Clean Water Act (CWA) Section 404 (Herdman, 1994b; Williams, 1993).

Although a wide variety of wastewater treatment systems designs are available for rural communities elsewhere (EPA, 1994a), the selection and implementation of optimum systems for rural Alaska's extreme environment is a difficult task. Wastewater treatment systems in rural Alaska are influenced by freezing temperatures, inadequate water supply, challenging topography, high seasonal flooding potential, and poorly-drained, permafrost-impacted soils (CSCE., 1986; EPA, 1994b; Olofsson and Schroeder, 1993; Troy, 2007; Williams, 1993). Unfortunately, many of the designs originally selected for use in rural Alaska were based on conventional temperate sanitation systems (Herdman, 1994a; Percival et al., 2003). Consequently, many of these systems have failed to adequately treat the wastewater (ANTHC, 2007; Cowater., 1993).

Currently, piped sewage systems, septic tanks and waste hauling systems are utilized in rural communities (Duigou, 2006). Larger rural communities (>1,000 residents) are usually equipped with in-home piped sewage and municipal piped distribution systems. In smaller communities piped sewage systems are available only for schools and washeterias (i.e. community buildings in which people can shower and do their laundry) (ANTHC, 2007; EPA, 1994b). In-home piped sewage systems are operated either through pressure, gravity, or vacuum technology (Duigou, 2006; EPA, 1994a). The disadvantages of installing piped in-house systems connected to municipal piped distribution systems include higher operation and maintenance costs (i.e. powering the pressure system and heat service lines) and problems related to distribution across varied terrain (Olofsson and Schroeder, 1993). Moreover, poor soil drainage, periodic flooding and ice-rich soils restrict the installation of affordable septic tanks (Olofsson and Schroeder, 1993). As a consequence of high installation and operation costs of piped systems, more than 35% of rural communities are lacked sufficient wastewater services as of 2008 (Duigou, 2006; Haley, 2000). In these communities, native residents are still using honeybuckets (5 gallon bucket

lined with a plastic bag used for human waste), as well as pit toilets and privies (ANTHC, 2007; Hennessy, 2008).

Disposal of wastewater is facilitated in constructed sewage lagoon systems (lined either with synthetic or sand material), non-constructed natural tundra ponds termed honeybucket lagoons, or septic tanks (Williamson, 2010). Constructed and non-constructed sewage lagoons treat the wastewater based on long term storage combined with sedimentation and natural facultative (i.e. anaerobic and aerobic) microbial degradation (Duigou, 2006; Williamson, 2010). The physical and chemical wastewater treatment requires proper operation and maintenance to ensure consistent secondary treatment process; however most rural communities lacking the technical, logistical, and administrative support to operate and maintain such basic utilities (Herdman, 1994b; Puchtler, 1978). The sewage lagoon discharge commonly depends upon the regional environmental settings and takes place either by direct release into an adjacent wetlands, surface waters or subsurface soil absorption. The wastewater accumulated in septic tanks is disposed by soil absorption systems, trenches, or pumped and disposed in a sewage lagoon (Duigou, 2006; Williamson, 2010). In rural communities with no piped in-home sanitation systems, wastewater and human waste materials are hauled manually or by truck, snowmobile, or all-terrain vehicle prior to disposal on the ground surface, in nearby pit bunkers, on frozen rivers, in the ocean or tidal plains, in tundra ponds or sewage lagoons (ANTHC, 2007; Hennessy, 2008).

The difference between unmanaged and managed constructed sewage lagoon, and non-constructed natural honeybucket sewage lagoon is illustrated in Figure I-4.

Improper wastewater disposal has been recognized as one of most critical threats to environmental pollution and human health (Imhof and Muehlemann, 2005). Particular concern has been expressed about the organic compositional change in wastewater, with the increased use and disposal of pharmaceutical substances, personal hygiene products and surfactants (Barnes et al., 2008; Cahill et al., 2004; Focazio et al., 2008; Glassmeyer et al., 2005; Kolpin et al., 2002; Kuemmerer, 2001; Musson and Townsend, 2009; Ternes, 1998). Synthetic organic compounds associated with wastewater such as personal hygiene and pharmaceutical products, surfactants, and flame retardants have been detected in ground and surface waters across the United States (Barnes et al., 2008; Cahill et al., 2004; Castiglioni et al., 2005; Ferguson et al., 2001; Focazio et al., 2008; Glassmeyer et al., 2005; Lajeunesse et al., 2008). In recent years, the US Geological

Survey collected and tested samples from streams, untreated drinking water sources and groundwater sites known or suspected to be influenced by human and agricultural waste. These sources, representing a cross section of US freshwater sources, were tested for approximately 100 organic wastewater contaminants (Barnes et al., 2008; Cahill et al., 2004; Focazio et al., 2008; Glassmeyer et al., 2005; Kolpin et al., 2002). These studies detected surfactant metabolites, pharmaceuticals and personal care products in 61% of tested streams and rivers (Barnes et al., 2008; Focazio et al., 2008; Kolpin et al., 2002). In Europe, pharmaceutical substances such as anti-inflammatory medications, antibiotics, stimulants, and antidepressant drugs have been detected in raw sewage, treatment plant effluents, surface and groundwater, manure, and soils since the 1980's (Kuemmerer, 2001, 2004).

Very little is known about these organic pollutants regarding transport processes, toxicological impacts posed to human and environmental health, and their ability to persist in the environment following offsite migration in cold regions (Ahel et al., 1994; Metcalfe et al., 2003; Nahir and Biggar, 1997). Therefore, their environmental impacts in rural Alaska, where treatment and disposal of wastewater is less controlled than other regions of the United States, is currently unknown. It is likely that organic constituents and pathogenic microbes originating from uncontrolled and untreated wastewater effluents and leaking systems are migrating into surrounding water resources. In addition, the concentration of microbial and organic constituents of untreated and uncontrolled wastewater discharge and leachate can be potentially higher than the concentrations observed in modern treatment plant effluents. Moreover, in arctic and subarctic communities underlain by permafrost, the hydrologic separation between drinking water sources and wastewater discharge facilities are often not well understood due to the interconnectedness of overly abundant surface water. Thus, this poses an additional risk of wastewater constituents co-mingling with drinking water sources.

1.2.4 Contaminant Transport Processes

Improperly designed and managed waste facilities can give rise to wide range of leachate constituents. In order to predict the possible environmental impacts of rural Alaska wastewater and solid waste leachate and to design suitable facilities, information is essential to create baseline knowledge of the chemical composition of leachate and to delineate potential transport

pathways. While numerical models exist to predict contaminant migration in temperate environments, little information is currently available on the movement and fate of contaminants in cold climate regions. The contaminant transport pathways evaluated in this study include transport of dissolved and particulate pollutants in surface waters, infiltration and migration of water borne pollutants into soils, and subsurface transport processes in frozen and unfrozen soils. Conceptually, environmental contaminant transport is a function i) of chemical and physical properties of the pollutant itself and transport media (water, soil, or air), ii) the rate of pollutant migration or mass flux, ii) the matrix resistance to mass transfer across interface or no-interface boundaries, iv) the diffusion or dispersion properties influenced by conductivity, mass, heat, momentum, and v) the physical, chemical and biological transformation processes influencing persistence in the environment (Alloway and Ayres, 1997; Holdgate, 1979; Schwarzenbach et al., 2003).

In surface waters, contaminant transport and dispersion processes are controlled by advection (mass movement) and diffusion (without net movement of water). These transport processes are driven by water temperature, density or salinity and water solubility of the pollutant (Alloway and Ayres, 1997; Schwarzenbach et al., 2003). The water-soluble pollutants are mobilized and transported as a function of stream discharge, water flow direction, concentration of soluble pollutants present in the water, biochemical or physical degradation processes, and the extent of retardation due to sorption on mineral surfaces (Alloway and Ayres, 1997; Maidment, 1993). Insoluble pollutants, in addition to the processes above, are also influenced by adsorption process on organic matter solids and colloids (small <0.001 mm charged soil particle complex of clay minerals, organic matter, and hydrous oxides) on soils and suspended sediments (Alloway and Ayres, 1997; Maidment, 1993). In arctic and subarctic regions, seasonal flush events play a large role in pollutant transport. Such seasonal flush events result from relatively intense snowmelt and rainfall events, which can either wash-off of adsorbed soil colloids at the surface of the topsoil or increase the soil moisture content to allow infiltration and percolation into the vadose zone (Alloway and Ayres, 1997; Maidment, 1993). Hence, a flush phenomenon not only increases the infiltration and percolation of soluble pollutants into soil profile, but also increases insoluble pollutant migration through sorption onto migrating soil colloids and organic matter (Maidment, 1993). In both frozen and unfrozen soils, infiltration is driven by the matrix potential (pore pressure) and the gravitational potential (Kane, 1983).

Soil particles are comprised of a mixture of liquid, gaseous, organic, and mineral constituents inhabited by a wide range of microbial organisms. Microbial organisms play a significant transformation role for physical, chemical, and biological decomposition processes (Alloway and Ayres, 1997). The liquid and gaseous phases occupy pores within and surrounding the aggregated soil particles (Brady and Ray, 2001). The liquid phase contains ions and soluble organic compounds, the concentration of which are determined by oxidation, reduction, adsorption, precipitation and desorption processes (Alloway and Ayres, 1997). Soil water movement through the soil matrix is determined by hydraulic conductivity (a measure of the soil's ability to transmit water) and water-retention characteristics (matrix potential and hysteresis) (Alloway and Ayres, 1997; Maidment, 1993). The soil physical and chemical properties affect soil water movement through differences in soil texture (sand, silt, and clay) and their associated water-retention characteristics (Alloway and Ayres, 1997). Specifically, contaminant transport in soil media is subject to processes driven by pH, soil moisture, soil texture and organic content (Lunde and Young, 2005; Selim and Iskandar, 2000). In unsaturated soils contaminant transport processes are affected by sorption and ion exchange effects, retardation, diffusion (movement due to a concentration gradient), or mechanical dispersion (mixing of the chemicals due to different flow velocities at the microscopic level) (Maidment, 1993). In saturated soil, contaminant transport through the soil matrix occurs within the liquid phase through connected pores by advection (movement with the average flow velocity of the liquid phase), diffusion or mechanical dispersion (Alloway and Ayres, 1997; Selim et al., 1999; Troide et al., 1993).

In arctic and subarctic regions, contaminant transport processes are also affected by frozen soils, including the active layer (e.g. topmost layer of the soils subject to seasonal freezing and thawing) and the permafrost layer (e.g. soils beneath the active layer, which remains frozen throughout the year). In the active layer, water movement and its phase changes are subject to natural cycles of freezing and thawing, and exhibit distinct hydrogeochemical characteristics such as heterogeneous soil structure, surface-related fluxes, low temperatures, peat-originating humus, soil acidity, and enrichment of dissolved ions (Hatva, 1989; Soveri, 1985), along with infiltration and percolation related to local precipitation events and surface hydrology (Michel, 1994). Freeze-thaw effects can include changes in pH and redox potential of the soil solution, thus initiating changes in transport and exclusion of dissolved ions during freezing (Maidment, 1993). Moreover, pollutants can redistributed during the freezing process by moving through the

conduits of unfrozen pore fluid that persist along soil particle surfaces (Han et al., 1999) or remaining in enriched water phase due to solute exclusion and migration along the freezing front (Ershov et al., 1994; Hallet, 1978; Ostroumov, 2001). In the active layer of arctic and antarctic soils, ionic transport was illustrated through the use of lithium (Li^+) tracer experiments. During freezing, it was demonstrated that ions mobilize in the active layer and migrate along concentration and temperature gradients (Claridge et al., 1996 b; Lunde and Young, 2005).

Volumetric moisture or ice content is a significant factor influencing transport processes through permafrost-affected soils. The volumetric moisture content of arctic and subarctic permafrost can vary substantially between 0 to 100%. In ice-rich permafrost (with high moisture content), the frozen soil acts as a barrier to subsurface liquid flow, thus limiting the majority of flow to lateral movement within the active layer (Dyke, 2001). In unsaturated permafrost with an average ice content of 10-15% (Boike, 1997; Mckay and and Black, 1973), a number of studies demonstrated that unfrozen water exists due to surface forces of soil particles and solute exclusion (Anderson and Morgenstern, 1973; Anderson et al., 1973; Tice et al., 1984). Unfrozen water can migrate at subzero temperatures along thermal, osmotic and pressure gradients (Burt and Williams, 1976; Claridge et al., 1996b; Horiguchi and Miller; Murrmann, 1973; Nakano, 1987, 1990; Smith, 1985), and solutes in soil water are subject to the same forces (Claridge et al., 1996a; Murrman, 1973). Murrmann (1973) concluded that because ions are mobile in unfrozen interstitial water, ion mobility is controlled by the same soil properties that determine unfrozen water content (grain size, solute content, bacterial activity). Nevertheless, the phase change between unfrozen and frozen water along the lower boundary of the active layer can inhibit diffusion by a factor of 10, thus leading to an accumulation of contaminants in upper permafrost (Murrmann, 1973).

1.2.5 Waste Leachate and the Impacts on Rural Alaska Environment

In addition to the previously-described challenges surrounding solid waste and wastewater management, the predicted changes in climate (ACIA 2004) pose additional challenges to rural Alaska communities in the coming decades. Rural communities underlain by permafrost are particularly vulnerable to landscape degradation imposed by a warming climate due to the sensitive hydrological system and their close location to pollutant sources. Although arctic and subarctic regions have received increasing attention to preserve or restore their perceived pristine

condition (Dyke, 2001), remediation efforts in rural areas have been directed primarily to oil and mine tailing contamination (Jensen et al., 1999). Historically, waste management practices have relied upon the perception that soils in permafrost areas are impermeable to miscible and immiscible contaminant mobility (Dyke, 2001; Kellems et al., 1991). However, studies have demonstrated several processes that can promote contaminant transport off of waste disposal sites in permafrost areas (Biggar et al., 2003; Dyke, 2001; Lunde and Young, 2005; Magee and and Rice, 2002). In discontinuous permafrost regions Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) have been both modeled and observed to move with the water phase along channels in the permafrost (Farris A. et al.; Hinzman et al., 2005). Moreover, free- phase hydrocarbons have been observed to migrate readily through unsaturated permafrost (Biggar et al., 2003; McCarthy et al., 2004). A laboratory experiment in frozen ground confirmed vertical and horizontal movement by ethylene glycol (Han et al., 1999). A lithium chloride tracer used as a proxy for heavy metal mobility concluded that contaminants tend to accumulate at the interface between the active layer and permafrost layer, and are subject to transport processes driven by soil moisture, texture, organic content, and topography (Lunde and Young, 2005). These studies all indicate that the perception of permafrost soils as impenetrable to contaminant transport is a flawed perception.

Observed climatic trends in arctic and subarctic regions include warmer temperatures over land and sea ice, a reduction in arctic sea ice coverage, a reduction in the extent of areas underlain by permafrost, increased ground temperatures, and changes in precipitation patterns across the arctic and subarctic region (AMPA, 2003). Long-term records of the near-surface permafrost temperature demonstrate a significant warming trend over the last 30 years. Recent data reveals an increase in soil temperatures of 1 to 3 degrees Celsius compared to long-term averages (Osterkamp and Romanovsky, 1999). As permafrost degrades in response to mechanical distribution (Yesiller et al., 2005), or climate change, thawed channels in the permafrost (taliks) can serve as conduits for rapid contaminant transport (Yoshikawa and Hinzman, 2003). The predicted change in subsurface flow regime due to permafrost degradation can potentially increase the mobility of waste pollutants into nearby water resources in arctic and subarctic regions. In areas where previously-frozen permafrost has recently thawed, soils conduct water and contaminants at significantly higher rates compared to continuously-thawed soils due to structural changes resulting from the thawing process (Dyke, 2001). In addition, as climate

warms, the depth and seasonal duration of the unfrozen soils will increase and with an anticipated increase of precipitation, thus increase the mobility of associated pollutants proximal to rural Alaska waste facilities.

Some studies have predicted a potential increase in surface water dissolved organic matter and inorganic constituents with permafrost thaw (Frey and McClelland, 2009), leading to an increased mass flux of ionic constituents delivered into arctic and subarctic watersheds (Nelson, 2003; Smith, 2005). As inorganic and nonpolar organic constituents can have a strong affinity for organic matter and soil colloids (Gounaris, 1993; Kjaergaard, 2003), these constituents can migrate with increased thaw-related sediment transport to surround water resources (Kjaergaard, 2003). In addition, sorption processes are often pH-dependent (Dixit, 1982; Kjaergaard, 2003), and sorption decreases in the presence of humic acids associated with tundra soils. Thus, the relative increase in unfrozen tundra soil volume associated with permafrost thaw may lead to an increase in the mobility of dissolved pollutants, especially given the anticipated increase in precipitation. Likewise, existing contaminants currently immobilized in frozen soils have the potential to be released as a consequence of permafrost degradation or erosion. These inorganic and organic contaminants may be expected to persist in the environment following offsite migration due to low temperatures and slow degradation rates (Kjeldsen et al., 2002; Vieno et al., 2005).

1.2.6 Waste Pollutant Impacts on Human Health and Subsistence Activities

Arctic and subarctic rural communities are particularly sensitive to pollutant exposure due to their subsistence activities, living environment, and use of traditional drinking water resources (Duffy et al., 1998; Egeland et al., 1998; Zender et al., 2003a). In the past, little attention was directed towards point source pollutants as their impacts were assumed to be insignificant considering the size and remoteness of rural Alaska communities. This assumption was based upon general notions relating the environmental impacts of point source pollutants to parameters less often observed in arctic and subarctic regions including high population density, relative affluence, the use of advanced industrial technologies, and high-yield agricultural practices (Alloway and Ayres, 1997; Meadows et al., 1992). Due to the lack of regular monitoring, limited information is available in cold regions regarding pollutant constituents in wastewater discharge and waste leachate, and their toxic effects and persistence. Thus, it is a difficult task to elucidate symptoms

of poor human and environment health resulting from cold region point-source pollutants (Hennessy, 2008).

Historically, Alaska Natives have a higher disease rate compared to U.S. or Alaskan whites, and the Alaska Native infant mortality rate is twice as high as that of Alaskan whites (ANTHC, 2009). Moreover, the incidence of cancer in Alaska Native populations is above the national average (ACR, 2002; ADHSS, 2006). Many outbreaks of diseases (e.g. Hepatitis A, bronchitis, impetigo, rashes, pneumonia, and endemic enteric, meningitis) in rural Alaska communities are associated with limited amounts of treated water available for drinking, personal hygiene, and removing human waste (Egeland et al., 1998; Esrey et al., 1990; Hennessy, 2008; Herdman, 1994b).

Several studies have examined the relationship between human health and solid waste sites. In one study, the CCTHITA surveyed residents about symptoms of poor health, personal characteristics, and solid waste disposals practices. Due to concerns over solid waste contamination, 57% of the respondents changed their subsistence practices (hunting, fishing, and gathering foods), and 52% changed their cultural/traditional activities (performing ceremonies, making baskets and other art/tools, and making traditional medicine) (CCTHITA, 2003; Zender and Sebalo, 2001a). In addition, 45% of the communities reported that at least some of their subsistence activities take place in the vicinity of the dumps, and 34% reported that drinking water resources are located with ¼ mile of their dumps (CCTHITA, 2003). Gilbreath et al. (2006) performed the first statistical study to evaluate pregnancy outcomes associated with rural dumps in Alaska Native villages. The result of the analysis indicated a correlation between high levels of anthropogenic chemicals in blood of pregnant women and proximity to waste sites. The authors indicated that this may be contributing to the newly discovered gender imbalance in the Arctic. Nationwide, the number of males being born is declining. Twice as many girls than boys are born in some Arctic villages in Greenland and Russia, and in some Greenland villages near the Thule American military base no boys are being born at all. The outcomes of this study also include, a low or very low birth weight, preterm birth, and intrauterine growth retardation (Gilbreath and and Kass, 2006). Moreover, mothers in villages with hazardous waste landfills had a higher proportion of low birth weight infants than mothers who were not exposed to hazardous waste facilities (CCTHITA, 2003; Gilbreath and Kass, 2006; Zender et al., 2001b; Zender and Sebalo, 2001a).

In 2004, a study at UAF confirmed that microbial indicators of fecal contamination (*Escherichia coli*, total coliform and *Enterococcus* sp.) are tracked from open dump sites back into the community on ATV tires and footwear. Indicators of fecal contamination, which portend the presence of human pathogens, were found throughout the community, in the local school, and at boardwalk locations directly adjacent to homes (Chambers et al., 2008). Source water assessments recently conducted by the ADEC rated the majority of public water systems utilizing surface sources in the Kuskokwim Delta region as being "highly" or "very highly" vulnerable to bacterial/viral impacts (ADEC, 2008).

Studies performed to assess wastewater and landfill leachate in moderate climates demonstrated the presence of hazardous pollutants and described the implication for the aquatic environment and human health (Jjemba, 2006; Koch and Calafat, 2009; Kuemmerer, 2001, 2009; Lincoln et al., 2007; Minh et al., 2006; Slack et al., 2005; Teuten et al., 2009; Vrijheid, 2000; Yu, 2005). Many of these pollutants are toxic and can accumulate in soil or sediments or percolate into nearby surface waters or down to the groundwater, where they have the ability to enter the food chain directly (Alloway and Ayres, 1997). For instance, heavy metals that are found in paint, car batteries, light bulbs, electronics (computers, TVs, cell phones, etc.) are known to cause renal disease and neurological harm in mammalian organisms and aquatic life (Yu, 2005). Cadmium and mercury in particular are known to bioaccumulate in mammalian and fish adipose tissue, where they are subject to biomagnification through the food web (Yu, 2005). Heavy metal exposure pathways have also been described in soils, based upon their uptake by plant roots and subsequent consumption by wildlife (Yu, 2005).

In recent years new emerging organic pollutants, such as surfactants found in many consumer products (laundry detergents, shampoos, cosmetics, household cleaners, and latex paints) (Metcalfe et al 1996), and personal hygiene and pharmaceutical products (Ferguson et al., 2001; Jjemba, 2006; Kuemmerer, 2008; Teuten et al., 2009) have received increasing attention. These organic pollutants biodegrade into more persistent short-chain molecules and occur widely in the environment due to their low water solubility and strong adsorption to suspended material (Tsuda et al., 2000). Their exposure to organisms can occur by extravascular routes either through absorption or ingestion and are influenced by the concentration of the metabolite at the site of action (Jjemba, 2006; Teuten et al., 2009). Because their toxicity remains constant even at low concentrations (Ferguson et al., 2001) these organic pollutants can interfere with normal

development in aquatic species or have the ability to disrupt the endocrine system (Newman and and Unger, 2003). Endocrine disruptors have chemical structures resembling estrogenic compounds, and can interfere with the transport, metabolism, elimination, binding action, synthesis, or secretion of natural hormones (Jjemba, 2006; Kuemmerer, 2008). For example studies have demonstrated that soft plastic materials can leach organic constituents including phthalates and bisphenol A (Mersiowsky et al., 2001; PHS, 2002). Phthalate metabolites and bisphenol A have been shown to disrupt the endocrine system and act as carcinogens in mammals and aquatic life (Teuten et al., 2009) (vom Saal et al., 2010).

1.3 Study Site Locations and Methods

1.3.1 Onsite Collection

In 2008, in collaboration with the EPA RARE team and the University entities performed a survey to a set of rural Alaska communities, requesting information about open dump conditions and concerns, and gaging community interest in further research. Five communities were ultimately selected for further research (Ekwok, Eek, White Mountain, Allakaket and Fort Yukon) based in part upon the environmental setting of their open dumps (open tundra, ponded site, and permafrost-impacted). Furthermore, two rural sewage systems were chosen to identify and quantify surface water concentration levels for selected organic compounds. This was intended to help formulate a better understanding of solid waste and wastewater processes across the broader region. Each selected community's waste site reportedly located less than 1-1.5 miles from their respective community therefore constituted a proximal nuisance. Moreover each waste site was located less than 1,000 feet from a water resource and potentially impacted by seasonal flooding from rain or snowmelt runoff. The selected community dumps included a 30+ year old trench-fill design on tundra ground (Ekwok), a 30+ old tundra pond in discontinuous permafrost region (Eek), a 30+ year old above ground dump located on bedrock (White Mountain), a 10+ year old above ground dump located on permafrost (Allakaket), and a 30+ year old above ground dump located on permafrost (Fort Yukon). The two wastewater systems studied are a constructed sand lined sewage lagoon and an existing pond used as a honeybucket lagoon. For each sample event, soil, surface and subsurface water samples were collected in and around the perimeter of dumps along with raw sewage water samples on two consecutive days in May and August over

duration of two years. Soil, surface and subsurface water detailed sampling method for microbial and chemical analysis are described in the following chapters. Additional community background and sample site specific information are presented in Appendix A.

1.3.2 Chemical Contaminants Tested

Chemical and microbial analyses were performed to identify potentially noxious constituents and pathogenic organisms in waste impacted soil, surface and subsurface water samples. The selected inorganic, organic and microbial indictor organisms are intended to serve as proxies for a wide range of contaminants with varying levels of migration potential. All analysis was conducted at the UAA, ASET and/or the UAF, WERC laboratory. The analytes investigated in this study are:

Heavy Metals (As, Cd, Cu, Hg, Pb, Zn): The heavy metal analysis results obtained from waste derived leachate and soil samples are represented in Chapter 1, a journal paper on "*Assessment of heavy metals in rural Alaska landfill leachate*". Heavy metal analysis results are described in Appendix C.

Microbial Analyses: Microbial indicator organisms were enumerated in soil and surface waters in and around the perimeter of selected communities' dumps and two sewage lagoons. The findings of the microbial analysis are presented in Chapter 2 journal paper on "*Partitioning and Transport Behavior of Pathogen Indicator Organisms in Cold Regions"*. Microbial indicator organism data are described in Appendix D.

Organic Pollutant Compounds: Solid-phase extraction and high pressure liquid chromatography-mass spectrometry (LC-MSMS) methods were developed for detecting low-level concentrations of pharmaceuticals, phthalates, and benzotriazole metabolites. The findings are presented in Chapter 3 journal paper on "*Detection of new emerging organic pollutants in rural Alaska landfill and wastewater system.*" Additional organic analytical data are depicted in Appendix E.

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1.5 Figures

Figure I-1: Illustrates the three most common landfill designs in rural Alaska (left) above ground; (mid) trench-filling; and (right) tundra pond.

Figure I-2: Illustration of rural Alaska open dumps extends.

Figure I-3: Surface water at landfill site (left) standing water; and seasonal flooding event at the landfill site (right).

Figure I-4: Illustration of rural Alaska unmanaged (right) and managed (left) constructed and non-constructed natural honeybucket (mid) sewage lagoons.

1.6 Tables

Table I-1*:* Alaska climate zones reported average temperature and precipitation (Shulski and Wendler, 2007).

Location	Average Temperature High (^{0}C)	Average Temperature Low (^{0}C)	Average Precipitation Snowfall (mm)	Average Precipitation Rainfall (mm)
Arctic	6	- 29	686	76
Interior	20	-27	1,702	178
West Central	13	-19	1,400	279
South Central	17	-14	1,600	660
Maritime	17	-9	1,700	711

Chapter II

Assessment of Heavy Metals in Rural Alaskan Landfill Leachate

Abstract

Many rural Alaskan communities are small, remote and lack adequate infrastructure or economic resources to properly manage solid waste. As a consequence, solid waste material is often disposed in rudimentary landfills from which leachate is neither collected nor monitored. Thus, these landfills pose a potential risk to the communities' proximal water and ecological resources. This study was intended to investigate heavy metal abundance and composition in four rural Alaska landfills, and evaluate the potential of heavy metals to leach and migrate offsite. Physiochemical parameters and metal constituents were analyzed in soils, surface waters, and subsurface waters collected in and around the rural landfills. The results indicate locally elevated heavy metal concentrations in all analyzed media. Mean enrichment factors (EFs) were calculated based upon control samples obtained up-gradient from each landfill. EFs in surface and subsurface waters at the landfills and at offsite locations within 50 meters down-gradient of the landfills were elevated in Co, Cu, Ni, Mn, Zn, Fe, Cr, Cd, and Pb. The mean EFs for waste impacted soils were significantly enriched in Pb and Cd. Metals were shown to leach from soils and solid waste materials into surface water preferentially during seasonal high water events such as snowmelt and heavy rain. As surface waters proximal to rural Alaska communities are closely linked to food and drinking water sources, contamination through leaching of landfills can potentially impact human health. The results of this study strongly recommend implementation of adequate monitoring and management practices to reduce this risk.

[1] Mutter, E.A., Hagedorn, B., and Schnabel, W. Fairbanks 2014. Assessment of Heavy Metals in Rural Alaskan Landfill Leachate. Prepared for submission in Environmental Geochemistry and Health.

1. Introduction

Rural Alaska arctic and subarctic communities are small (< 1,000 population), remote and located in diverse geographic areas. These areas range from coastal to open tundra to mountainous regions, and can be composed of different bedrock lithologies. In addition, rural communities are scattered across five distinct climate zones including arctic, interior, west central, south central, and maritime. Moreover, rural Alaska communities exhibit differences in abundance and depth of permafrost, as well as differences in the abundance and distribution of wetlands (Olofsson and Schroeder, 1993; Patterson et al., 2012), both of which have strong influence on the transport and fate of pollutants. While the climatic and geographic differences between rural Alaska communities are vast, many share a common socioeconomic milieu such as small local economies and tax bases, high fuel and shipping prices, short construction seasons, and lack of sufficient local engineering expertise (i.e. trained personnel and local servicing expertise). These conditions, in addition to the stark physiographic and climatic conditions, can pose a significant challenge to adequate waste disposal practices (ANTHC, 2007; Duigou, 2006; Patterson et al., 2012; Troy, 2007).

Historically, many rural Alaska landfills have been open dumps developed without proper site assessment, landfill liners, leachate collection systems, or capping and monitoring requirements (EPA, 1998). In many instances, generated waste materials are deposited directly with little or no waste separation. Landfills are located in tundra ponds, above ground, or in pre-existing or constructed, often depressions, which are often water saturated and underlined by permafrost. Moreover, traditional dumps are operated without site control and hydrological consideration to minimize environmental contamination through leachate (Patterson et al., 2012; Zender et al., 2003). In arctic and subarctic dump sites, migration of leachate into the environment has been observed to occur most frequently in conjunction with seasonal flooding resulting from ice-dams, snowmelt, and/or heavy rain events (Patterson et al., 2012). The excess water during these events infiltrates the waste material, dissolves inorganic and organic constituents and percolates into the surrounding environment (EPA, 2009; Kjeldsen et al., 2002). In addition to these seasonal events, climate change-related thawing of permafrost and mass wasting can potentially create new hydrologic pathways for offsite migration of waste leachates.

In the past, heavy metal contamination of water resources and the surrounding environment by waste leachate was assumed to be insignificant considering the size and remoteness of rural

Alaska communities (Alloway and Ayres, 1997). However, the close proximity of community landfills to local food and water resources could pose a threat to these areas, especially given the recent changes in waste streams that now include the residues of modern lifestyles (Matsuura et al., 2008). Studies of municipal landfills have demonstrated abundant heavy metals in leachates from a high variety of waste materials including electronic wastes, paints, cleaners, vehicle maintenance products, batteries, food packaging containers (plastics, tin and aluminum), as well as construction and demolition materials (Dyke, 2001; Gounaris and Anderson, 1993; Kalyuzhnyi and Gladchenko, 2004; Kjeldsen et al., 2002; Lincoln et al., 2007; Øygard et al., 2004; Slack et al., 2005; Townsend, 2011; Vrijheid, 2000).

Landfills constructed without engineered liners, leachate collection systems, and adequate leachate treatment have a demonstrated propensity to leach metal constituents into the surrounding water resources (Christensen et al., 1994, 2001), but only few cases have been described for rural landfills in cold climates (Kjeldsen et al., 2002). Young and Lund (2006) studied an arctic waste site in Canada to evaluate cadmium and lead mobility from an open landfill. Their results demonstrated a higher mobility of cadmium compared to lead due to differences in adsorption coefficient of these elements (Ahel et al., 1994; Buol and Hole, 1961; Gounaris and Anderson, 1993; Kjaergaard et al., 2004; Young and Lund, 2006). A similar study conducted at a central arctic municipal waste site in Pangnirung Nunavut, Canada observed increased trace metal concentrations (Cd, Pb, Cu, Fe, and Zn) in water and sediment samples (Haertling, 1989). Both studies indicate heavy metal migration from a point source to the surrounding environment in cold climates with limited rainfall and permafrost abundance.

Mobility of heavy metals strongly depends on pH and redox condition as well as hydrologic conditions such as water saturation and soil porosity. In permafrost affected areas, only the uppermost layer of soil is thawed during summer (active layer), while the underlying soils remain perennially frozen (permafrost). In many instances, the pore space in the underlying frozen layer contains a large fraction of frozen water, thus limiting its effective porosity. Due to its limited depth (0.2 m to 1.5 m) and the relative impermeability of frozen ice-rich soils, the active layer is often water saturated or water logged in lowlands. As a result of the permafrost barrier, transport of water is often restricted to surface processes, and thus more highly dependent upon surface topography compared to hydrologic systems in warmer climates where deep percolation plays a

larger role (Alloway and Ayres, 1997; Lunde and Young, 2005; Maidment, 1993; Michel, 1994). Therefore, in permafrost areas with sloped topography, rain or snowmelt events can have an exaggerated impact upon the mobility of metals through mobilization of soluble species, or mobilization of metal species adsorbed to eroded sediments or organic colloids (Kjaergaard et al., 2004; Ledin, 1993).

In unsaturated soils most heavy metals are adsorbed to soil grain surfaces and their mobility is limited to mechanical dispersion (Maidment, 1993). However in saturated soils, heavy metals are also present in the dissolved phase, so transport also occurs by advection and diffusion (Dash et al., 1997; Alloway and Ayres, 1997; Impellitteri et al., 2001; Selim et al., 1999; Troide et al., 1993). In arctic and subarctic regions, hydrogeochemical processes are often affected by cycles of freezing and thawing of the active layer. The active layer itself is typified by heterogeneous soil structure, low turnover rates of organic matter leading to peat-originating humus and soil acidity, and enrichment in iron oxyhydroxides and oxides in aerobic horizons (Alloway and Ayres, 1997; Hatva, 1989; Lunde and Young, 2005; Selim and Iskandar, 2000; Soveri, 1985). Furthermore, solute exclusion Langmuir (1997) during active layer freeze-back can lead to a change of solute speciation caused by changes in pH and redox potential (Maidment, 1993). Moreover, active layer freeze-back can also concentrate metals in the unfrozen water phase (Boike, 1997; Boike et al., 2008) and re-distribute them via the conduits of unfrozen pore water that persist along frozen soil particle surfaces (Han et al., 1999), or along with newly-excluded metal species located at the freezing front (Ershov et al., 1994; Hallet, 1978; Ostroumov et al., 2001). Such migration processes have been demonstrated in tracer experiments using Li^+ ions (Claridge et al., 1996; Lunde and Young, 2005). Finally, heavy metal persistence in cold region soils may also be influenced by the relatively low biological activity present in such soils (Kjeldsen et al., 2002; Vieno et al., 2005).

In order to predict the possible environmental impacts of rural Alaska landfills, this study attempted to create baseline knowledge regarding the abundance and composition of heavy metals in waste leachate at rural Alaskan open waste sites during specific seasonal events (snowmelt, rain events). Four rural landfills in arctic and subarctic environments were sampled during different seasons of the year. Soil, surface and subsurface water were collected along potential hydrological pathways at increasing distances from the landfills themselves. Samples were analyzed for metals in the dissolved and particle-bound form, and extracted to evaluate

metal mobility and bioavailablity. Control sites outside the catchment area of the waste sites were collected to evaluate the geogenic background concentrations.

2. Study Sites

The study sites are located in the vicinity of four rural Alaska communities: Ekwok, Eek, Fort Yukon, and White Mountain landfills. The selected landfills are situated in different arctic and subarctic environments (e.g., open tundra, ponded site, permafrost and permafrost-impacted) and reported to be in close proximity to the community as well as impacted by seasonal flooding during rain events or snowmelt. Location of the study communities as well as photographs of the dump sites are illustrated in Figure 1.

Ekwok a community of 130 residents is located along the Nushagak River, 69 km northeast of Dillingham and 302 km southwest of Anchorage (Census, Bureau, 2010). Ekwok's coastal region geology is characterized by granitic rocks and alluvial, fluvial, and glacial deposits comprised of gravels, sands, silts, and clays (Glass, 1987). The soils are typified by poorly drained acidic silty soils on south-facing highland slopes that remains frozen until mid-summer, and poorly drained organic matter and peat rich soils on north-facing slopes with permafrost at approximately 70-130 cm depth (Rieger, 1965; Rieger et al., 1979). Ekwok is primary influenced by a maritime and continental climate with temperature ranging from -43°C to 29°C, and average precipitation of 140 mm rain and 140.2 cm of snowfall (Shulski and Wendler, 2007). The approximately 30 year old below ground landfill (trench-fill design) is located in tundra approximately 2.4 km northeast and upland of the village. The landfill covers an area of 2.3 km^2 and is 3-5 m deep creating a 22% slope towards the lowland area.

Eek is located on the south bank of the Eek River within the Yukon-Kuskokwim delta. The community of 208 residents is situated 19 km east of the mouth of Kuskokwim River and approximately 56 km south of Bethel (Census, Bureau, 2010). Geology of the region is characterized by igneous metamorphic and sedimentary rocks units ranging in age from Ordovican to Cretaceous and alluvial and fluvial deposits of gravel, sand, silt, and clay (ADEC, 2011). The surrounding region is mostly flat, with a few meters of elevation marking the delineation of major drainage basins. Tundra ponds are heavily distributed throughout the region,

and the larger ponds are generally underlain by thawed soils. Smaller ponds and drier areas may or may not be underlain by permafrost. Consequently, the area represents a complex hydrological system that is influenced by tides, permafrost, and surface water (ADEC, 2011). The climate is characterized by west central climate with temperatures ranging from -44°C to 30°C, and average precipitation of 406.4 mm rain and 134.4 cm snow (Shulski and Wendler, 2007). The approximately 30 year old, ponded landfill covers an area of 0.8 km^2 and is located less than 1.6 km away from the community. Perennially-saturated tundra ground with standing water occurs around the landfill, but no flooding is observed (Patterson et al., 2012).

White Mountain is located 100 km east of Nome on the Seward Peninsula on the west bank of Fish River and has a population of 224 residents (Census, Bureau, 2010). The regional geology is described as Ordovician and Devonian sedimentary rocks and alluvial and fluvial deposits of sand, silt, and gravel (West and White, 1952). White Mountain is characterized by shallow continuous permafrost and wet tundra ground; however, south-facing slopes may contain permafrost discontinuities below the vegetative layer (Shulski and Wendler, 2007). The climate is influenced by transitional west coastal climate with temperature ranging from -48°C to 37°C, and average precipitation of 432 mm rain and 172.7 cm snow (Shulski and Wendler, 2007). The approximately 30 year old landfill is situated above ground in an upland area approximately 400 m east of the village and north of Fish River. The landfill covers an area of 0.6 km^2 that rises up to approximately 4.5 m, creating 18% slope east/southeast towards the lowland area. Soil at the landfill is described as silty-clay and gravel underlain by limestone at approximately 1.5 m depth. Standing water occurs during snowmelt and rain events. The natural drainage area lies to the east/southeast side of the landfill.

Fort Yukon is a community of 600 residents located at the confluence of the Yukon River and Porcupine River, approximately 233 km northeast of Fairbanks (Census, Bureau, 2010). Fort Yukon is situated in the low-lying Yukon Flats characterized by vast areas of forested wetlands and bogs underlain by discontinuous permafrost. The region is characterized by Cenozoic sedimentary rocks of sandstone, siltstone, shale and alluvium, glacial, eolian and beach deposits, which is composed of fine clay-loam and is affected by cryoturbation in permafrost areas (Timothy et al., 2000). The climate is a cold continental climate with temperatures ranging from -54°C to 33°C, and an average precipitation of 304.8 mm rain and 157.5 cm snow (Shulski and Wendler, 2007). The approximately 30 year old above-ground landfill is located in an upland area

2.4 km from the community. The landfill encompasses an area of approximately 0.2 km^2 and is situated along the edge of an old river bank 8-15 m higher than the lowland area, creating a 32% slope. At the lowland area shallow soil consists of organic peat material with a permafrost table at approximately 40 cm in depth. Currently the landfill is reported as closed and covered with gravel; however establishment of a new permitted constructed landfill is in progress. Meanwhile, waste material is disposed on the outside border of the old landfill, and is treated via above-ground burning.

3. Methods and Materials

3.1 Onsite Sample Collection

A general site evaluation was conducted at each location using pre-existing maps, well-logs, and local knowledge to identify likely hydrologic pathways and to identify locations for control sites. Surface waters were collected at the landfill, 1-50 m down-gradient, 50 to 3,000 m down-gradient and 1-50 m up-gradient from each landfill. To evaluate heavy metal leachate produced by waste at different stages of decomposition, soil and surface water samples were collected proximal to newly disposed waste material as well as proximal to waste that had been in place for a long period of time and subject to at least partial degradation. In addition, samples were collected at burn boxes or open burned area. Soil samples (100 g) were obtained from the organic and mineral horizon (up to 30 cm depth) for soil water content, soil pH, and metal analysis. Control samples of soil and surface water were collected from undisturbed sites at each location. Surface water samples were collected along hydrological pathways on the surface and subsurface. Subsurface water was obtained above the permafrost table using piezometer (Solinst Probe System) and Rigid Porous Polyethylene (RPP) passive samplers at each landfill. Surface and subsurface waters were measured *in situ* for pH, electrical conductivity (EC) and temperature using an YSI Professional Plus or Combo Hanna meter, and alkalinity was determined with AquaCheck® Test Strips. Soil pH was measured in the laboratory in a 1:2.5 (v/v) water-soil suspension using a digital pH meter following the method procedure of Radojevic and Bashkin (1999). The number of samples obtained from each location and sample site are listed in Table 1.

3.2 Laboratory Analyses

For dissolved metals, 60 mL of water was filtered through 0.45 μm nylon syringe filter immediately in the field and acidified with 1 mL of 65-70% (v/v) OmniTrace Ultra nitric acid (HNO_3) after arrival in the laboratory. Surface and subsurface water samples for total dissolved solutes were acidified in the field before filtration and filtered after arrival in the laboratory. Acidification before filtration ensures to recover metals that are adsorbed to mineral surfaces or bound to colloids. All filtered and acidified samples were stored at 4^{o}C until analysis. Anion samples were filtered in the field and stored at 4^{o}C until analysis. Soil samples were oven dried in 43^{o}C. Approximately 1 gram of dried soil sample was weight out for digestion to 1 mg accuracy and extracted following EPA method 3050b. Cation analysis for soil and water samples were conducted based on EPA method 200.8 using the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Agilent 7500c) with reaction cell. Total organic carbon (TOC) was measured using Shimatzu TOC-VHCN analyzer. Total suspended solids (TSS) were determined by weight difference between empty filter and filter with oven dried (105^{o}C) sediment using 0.7 μm glass fiber filters (GC-C, Whatman). Soil water content was verified by weight difference between wet and oven dried soils at 110^{o}C for 24 hours. Standardized sieves with the size of 2 mm to 62 μm for sand, 62 to 3.9 μm for silt and < 3.9 μm for clay faction) was used to determine soil particle distribution.

3.3 Data Reduction

Normalization to element was performed to eliminate changes in metal concentration caused by dilution during heavy rain events and snowmelt, or through concentration during dry periods. In addition element ratios were normalized to the same element ratio measured in control sites to distinguish between the leachate derived increases of metal concentration from the geogenic background. The normalizing element ratios from potential affected sites to element ratio of control sites were then used to calculate an enrichment factor (EF) as described by Baut-Menard and Chesselet (1979): $EF = [(C_1M_e/C_{1n})/(C_2M_e/C_{2n})$,

where C_1M_e is the observed metal content in the environment; C_2M_e = the observed metal content in the control sites; C_{1n} is Na for water and Al for soils in observed environment, and C_{2n} is Na

for water and Al for soils in the control sample. The five contaminant categories established for EFs are listed in Table 2.

4. Results and Discussion

4.1 Physiochemical Characteristics of Surface and Subsurface Waters

Physiochemical characteristics of surface and subsurface water are listed in Table 2. The pH levels in leachate impacted surface and subsurface waters (see Table 1 A, B, and D) ranged from 5.7 to 8.7. The pH range of surface water samples collected 1-50 m down-gradient from Ekwok and 50-3,000 m down-gradient from Eek were generally lower than pH values observed in White Mountain and Fort Yukon at any specific sampling site (A-D). The sampling sites (B) from Ekwok and (C) from Eek are situated in lowland areas with poorly drained organic rich soils and peat, which have a high abundance of humic acids that lower the pH values and potentially can increase metal mobility. A pH range of 6.8 to 10.3 was measured for subsurface water at the Eek tundra pond, located adjacent to the community sewage lagoon. The higher pH could indicate that sewage seepage of organic nitrogen and ammonia nitrogen resulting from anaerobic processes are migrating into subsurface waters (Maidment, 1993). The higher pH values for White Mountain and Fort Yukon reflect the occurrence of limestone in these locations, which can buffer the soils and inhibiting mobility of metals. Infiltration of rain and snowmelt, with nominal pH values in equilibrium with atmospheric CO_2 (pH 5.4), can potentially increase metal mobility. High levels of specific electrical conductivity (EC), total suspended solids (TSS), and total organic content (TOC) were observed in surface waters directly in the landfill (A), in close proximity to the landfill (1-50 m down-gradient, B) and in subsurface waters (D) compared to the control sites (Table 2). The EC in waters at the landfills ranged between 178.0 and 2,232.0 μS/cm, between 77.0-1,920.0 μS/cm for water in close proximity to the landfills (1-50 m down-gradient), and between 400.0-2,300.0 μS/cm for subsurface waters. The variability is likely due to dilution by a high volume of water resulting from rain and snowmelt, or concentration due to evaporation during the dry season. In addition, with respect to waste composition a lower pH in the range of 6.1 to 7.2 and higher range of EC between 1,220.0 and 1,350.0 μS/cm were observed in surface waters in close proximity to burned and newly disposed waste material at each landfill location. The TSS in surface and subsurface waters at landfills and in close proximity to the landfills was

approximately 100 times higher than the surface water TSS observed in areas further away from the landfills (50-3,000 m), and approximately 1,000 times higher than the TSS observed in the waters at the control sites. The TSS at control sites was in the range of rainwater < 10 mg L^{-1} (Maidment, 1993). TOC and alkalinity (reported as $CaCO_3$) were only measured once throughout the sampling events. Total alkalinity in surface and subsurface water ranged between 37.5 and 432 mg L^{-1} with higher values in White Mountain and Fort Yukon landfills. While the high alkalinity and pH seems to coincide with the abundance of limestone, it is noted that control sites in White Mountain and Fort Yukon landfills are not elevated, and therefore increased alkalinity may partly be related to landfill material. A large variability in physiochemical characteristics was observed within the individual landfills during the same sampling event, thus indicating a high degree of variability and limited mixing within individual landfills (Table 3).

4.2 Physiochemical Characteristics of Soils

The physiochemical characteristics for soil profiles are reported in Table 4. The pH values for all soil samples obtained from the organic and mineral layer (0-30 cm in depth) ranged from 5.1 to 8.6, with higher pH values in soils from White Mountain and Fort Yukon landfills. The soils at Eek, by comparison, which were collected in saturated tundra ground composed of poorly drained and organic rich soil, had a lower pH likely due to the presence of organic acids (Ping et al., 2008). In general, the control soil pH values were slightly lower than the landfill affected soils. Low pH and/or changing redox conditions due to presence of organic acids and/or water saturation of soils during rain and snowmelt events can increase mobility of heavy metals (Brady and Ray, 2001). Mobility of some metals decreases with increasing pH as a consequence of adsorption to grain surfaces or due to precipitation or complex formation of insoluble carbonates and organic hydroxides (Dixit, 1982; Johnson et al., 1996; Yu et al., 1997). Soil pH values below 6 can lead to desorption of some of these metals and prevent carbonate precipitation, thus favoring metal mobility. The predominant particle size was observed to be clay (< 3.9 μm) and silt (62-3.9 μm) fractions for all landfill impacted and control samples. The high clay size fraction provides a high surface area, thus enhancing adsorption capacity of metals in the soil (Alloway, 1990; Ledin, 1993). In addition to changes in pH and redox, heavy rain can lead to flushing of soils and increase colloid transport to surface water through surface runoff (Kjaergaard et al., 2004)

4.3 Metal Distribution in Surface and Subsurface Waters

The distribution of metal concentrations in surface and subsurface waters are presented in Table 5. The common elevated trace metal concentrations observed in waste leachate impacted waters compared to control sites were Al, V, Co, Fe, Cu, Mn, Cr, Zn, Pb, Cd, and Ni. All trace metal concentrations yielded a significant variability (Analysis of variance $p < 0.05$). The variability in leachate can be attributed to a variety of factors including differences in waste constituents, waste age, waste density, and differences in treatment and disposal practices (Kjeldsen et al., 2002; Yesiller et al., 2005). In addition, natural factors including the amount of precipitation and site-specific soil characteristics, which determine moisture retardation, surface water infiltration, and flow pathways (Åkesson and Nilsson, 1997; Christensen et al., 1994; Chu et al., 1994; Kjeldsen et al., 2002; Sundsbak, 1971), contribute to variability as well. Overall a lower mean concentration of trace metals in control and leachate impacted water samples was observed in surface waters during snowmelt, when the ground was still frozen and infiltration was likely limited. In the fall during rain precipitation, dilution is only minimal. The absence of dilution in fall indicates the accumulation of trace metals on and in the soil during the dry summer season and better mobilization of metals due to larger infiltration of water into the ground and is in agreement with observations made by (Kjaergaard et al., 2004). The metal concentrations detected in this study (Table 3) were consistently lower than those observed in municipal landfill leachate in other regions with moderate climate (Christensen et al., 1994; Kjeldsen et al., 2002) with an average concentrations of Cd (2-20 $\mu g\ L^{-1}$), Ni (100-200 $\mu g\ L^{-1}$), Zn (500-2,000 $mg\ L^{-1}$), Cu (20-100 $\mu g\ L^{-1}$), Pb (50-200 $\mu g\ L^{-1}$), and Fe (10-200 $mg\ L^{-1}$) (Christensen et al, 1994; Jensen et al., 1999). The average metal concentration detected in surface and subsurface water in and around rural landfills generally followed the order Al > Fe > Mn > Zn > V > Cu > Cr > Pb > Cr > Ni > Co > Cd (Table 5). Overall, the highest metal concentrations were observed in landfill subsurface waters (group D), followed by surface waters 1-50 m down-gradient of the landfills (group B), followed by landfill surface waters (group A), surface waters 50-3,000 m down-gradient from the landfills (group C), and finally surface waters at the control sites (group E). The overall metal concentrations were highest in the Ekwok landfill, followed by the Fort Yukon landfill, the White Mountain landfill, and the Eek landfill. A significant positive correlation ($R^2 > 0.8$) of metals existed between Cr, Co, and Cd, Mn and Ni, and between Al, Cu and P, presumably attributable

to contributions from waste material (Table 6). Heavy metals typical for household waste and machinery including paint, car batteries, light bulbs or electronics are known to cause health impacts in humans, mammalian organisms and aquatic life when introduced into the environment (Clement et al., 1996; Fagbote and Olanipekum, 2010; Ha et al., 2009; Klinck and Stuart, 1999; Vrijheid, 2000; Yu, 2005). For example Cd and Pb are known to bioaccumulate in mammalian and fish adipose tissue, where they are subject to biomagnification through the food web (Huu et al., 2010; Peramaki and Decker, 2000; Yu, 2005). Heavy metal exposure pathways have also been described in soils, based upon their uptake by plant roots and subsequent consumption by wildlife (Huu et al., 2010; Peramaki and Decker, 2000; Yu, 2005).

4.4 Trace Metal Distribution in Soils

The average concentrations of acid leachable metals in this study's landfill-impacted soils were 1 to 2 orders of magnitude higher than the concentrations observed in surface and subsurface waters. The distribution of trace metal concentration in soils is presented in Table 7. The metal concentrations in the landfill impacted soils were highly variable compared to the concentrations in the control site soils. Due to the variability in the landfill soils, the average metals concentrations were not clearly distinguishable from the control samples in all instances. While landfill soil concentrations of Cd (0.5-4.2 mg kg^{-1}), Ni (18.8- 27.1 mg kg^{-1}), Pb (8.7-106.1 mg kg^{-1}) and Zn (56.0-453.9 mg kg^{-1}) generally appeared to be higher than the controls, the concentrations of Al (10.3-16.0 kg kg^{-1}), Co (6.0-7.7 mg kg^{-1}), Cr (19.0-38.3 mg kg^{-1}), Cu (14.5-172.4 mg kg^{-1}), Fe (5.2-29.5 kg kg^{-1}), and Mn (249.8-522.8 mg kg^{-1}) in the landfills generally did not appear to be higher than the controls. The highest average metal concentrations were found in Eek landfill soils. This landfill is a ponded site in saturated tundra ground underlain by permafrost and influenced by coastal tides. The subsurface water in this landfill has high pH and alkalinity (Table 3) and therefore low metal mobility is expected. Significant correlations were observed between soil concentrations of Cr, Zn, Pb and Cd, supporting the notion that they arose from common sources (Table 8). Lower regression coefficients were observed between Ni, Cu and Fe (Table 8). As a positive correlation was found between Cr, Cd and clay size fraction, due to high surface area and general neutral to light alkaline pH.

4.5 Metal Enrichment Factor (EF)

Enrichment factors (EF) are generally used to identify areas in an environmental setting where elements are enriched over the background concentrations in selected control sites. EFs of leachate impacted surface and subsurface waters are calculated based on the average total and dissolved load (Baut-Menard and Chesselet, 1979). Control samples are considered to be unaffected by waste deposits and thus reflect the geogenic background metal concentrations. Na and Al were selected as normalizing elements for water and soil samples, respectively. The selection of these elements was based upon their chemical and geochemical characteristics. Na is a conservative element in aquatic environments, while Al is a stable and relatively immobile element in soil environments. EFs of the total load indicate if metals are transported or accumulated with particles or colloids, while EFs of dissolved load indicate if metals are transported or accumulated specifically in the water phase. The Log-EFs distribution of metals for each sampling location is illustrated in Figure 2 for total metals, Figure 3 for dissolved metals and in Figure 4 for soils.

EFs for total and dissolved heavy metals were observed in the following decreasing order, based upon site type: subsurface water (group D) < surface waters 1-50 m down-gradient from the landfill (group B) < landfill surface waters (group A) < surface waters 50-3,000 m down-gradient (group C). The highest EFs for total metals were observed at the White Mountain landfill, followed in decreasing order by the landfills in Fort Yukon, Ekwok, and Eek. The highest EFs for dissolved metals were observed in the Ekwok landfill, followed in decreasing order by the landfills in Eek, Fort Yukon, and White Mountain. The trends of metal concentrations closely followed the trends observed with respect to pH: higher total metal loads were observed in landfills that had higher pH, therefore higher tendency to adsorb metals to soil surfaces. Higher EF's in dissolved metals was observed in more acidic environments where metal adsorption to surfaces would be expected to be lower (Ekwok and Eek landfills).

EFs for total and dissolved heavy metals were observed in the following decreasing order, based upon site type: subsurface water (group D) < surface waters 1-50 m down-gradient from the landfill (group B) < landfill surface waters (group A) < surface waters 50-3,000 m down-gradient (group C). The highest EFs for total metals were observed at the White Mountain landfill,

followed in decreasing order by the landfills in Fort Yukon, Ekwok, and Eek. The highest EFs for dissolved metals were observed in the Ekwok landfill, followed in decreasing order by the landfills in Eek, Fort Yukon, and White Mountain in accordance with increasing trend in pH. The trends of metal concentrations in the total load (dissolved and adsorbed) closely follow the trends observed with respect to pH: higher total metal loads were observed in landfills that had higher pH, therefore higher tendency to adsorb metals to soil surfaces.

In general, the surface waters were more highly enriched in total metal concentrations compared to dissolved metal concentrations (Figures 2 and 3). This result supports observations from Jensen et al. (1999) that with exception of Zn, heavy metals in leachate polluted surface and subsurface waters are strongly associated with soil particles, and that heavy metals can form complexes with organic molecules and mobilize with the water phase (Ostroumov et al., 2001). The average EF's for landfill soils were Pb (22.0) > Cd (17.7) > Mo (4.5) > Zn > (4.0) > Cu > (3.5) > Ni (2.1) > Fe (2.4). Although the EF's appeared to be highest in Eek landfill soils, the values were not found by analysis of variance ($p < 0.05$) to be higher than the other tested landfills. Potential sources of metal species indicated in other studies include Ni from tin cans, Fe from steel scraps, Zn and Mo from batteries and fluorescent lamps, and Pb from Pb batteries, chemicals for photograph processing, lead-based paints and pipes (Iwegbue et al., 2010; Mor et al., 2006; Zwiener et al., 2002).

4.6 Implications for Human Health and Climate Change

Heavy metals can be toxic, can persistence in soil or sediments, can mobilize in surface and subsurface waters, and can biomagnify in the food web (Huu et al., 2010; King, 1999; Peramaki and Decker, 2000; Purves, 1985). The mobilization of metal constituents from rural Alaska waste sites into nearby waters may be exacerbated with a warming climate and/or an increase in precipitation. It is anticipated that the depth of the active layer (seasonal unfrozen top soil layer) will increase, as well as the fraction of the year in which it remains unfrozen. Especially in the presence of increased liquid precipitation, this would increase the mobility of the associated heavy metals. This study's results strongly indicate a need for increased assessment and monitoring of open landfills in rural Alaska. A step towards reducing the risk of further

contamination would be to initiate a state regulation designed to promote active removal of heavy metal constituents from the solid waste stream.

5. Conclusions

Metal concentrations observed in water and soils proximal to the rural Alaska landfills were highly variable. The metal concentrations in surface waters showed an overall decreasing trend downward from the landfill locations. Strong seasonal weather patterns including snowmelt and heavy rains influenced metal concentration and distribution. During snowmelt, metal concentrations in surface water were relatively low, presumably due to limited interaction between meltwaters and frozen soils. Accumulation of heavy metals on the soil surface during the drier summer season resulted in higher concentrations during fall rain events. In those instances, the rainfall runoff mobilized metals due to their association with soil particles. Sites with relatively high pH values yielded relatively low metal concentration in the dissolved load, thus indicating adsorption of metals to soil surfaces. The enrichment analysis indicated moderate to extreme enrichment of metals including Cu, Ni, Mn, Cd, Co, V, Zn, Al, and Pb in surface and subsurface waters, while the soils were found to be highly enriched (EF > 5) in Cd, Cu, Zn, and Pb.

This study indicated that uncontrolled snowmelt and rainwater runoff from rural Alaska landfills can transport heavy metals into the surrounding environment either as dissolved species or adsorbed to particles. The mobility of metals is strongly controlled by pH which is depends on vicinity of sewage lagoons and lithology. The detected metal concentrations are high enough to potentially impact rural communities' traditional drinking water and subsistence food resources, which can even increase due to climate change in the future.

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7. Figures

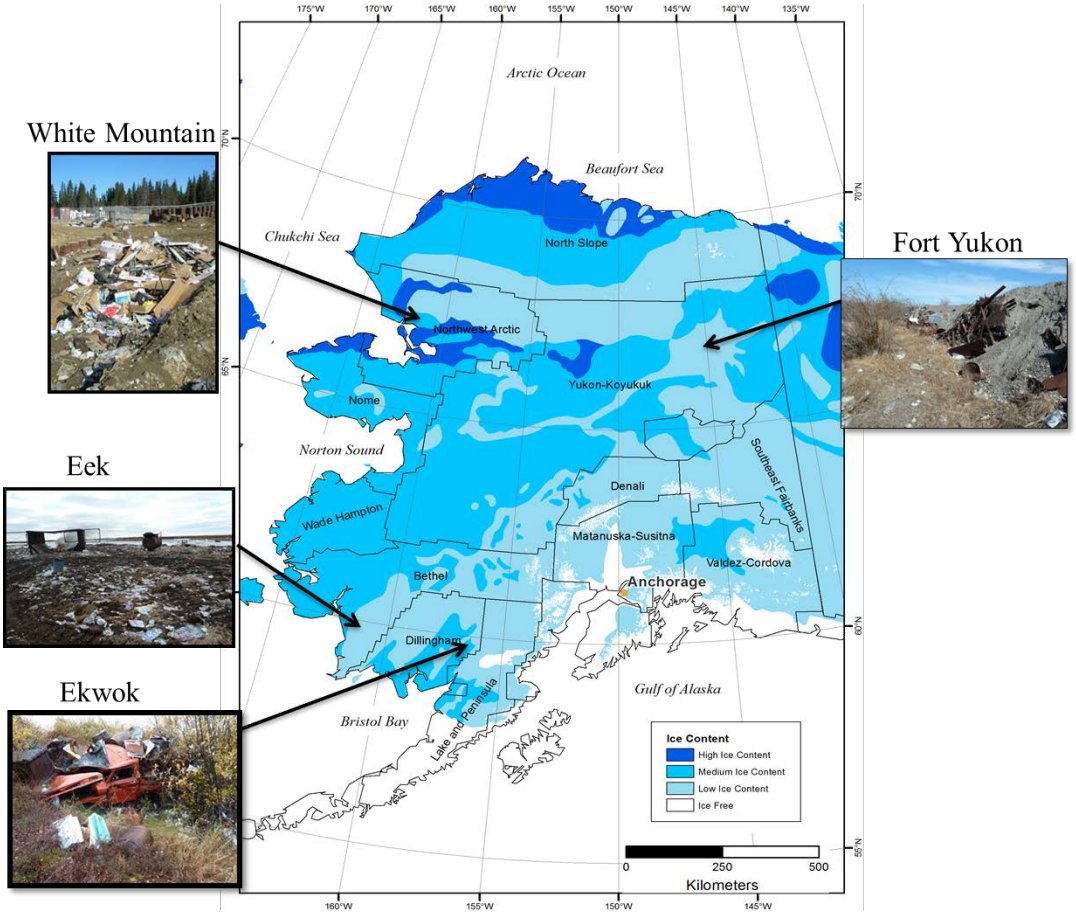

Figure II-1: Illustration of sampling location, region and landfill design: upper left White Mountain, upper right Fort Yukon, lower left Eek, lower right Ekwok.

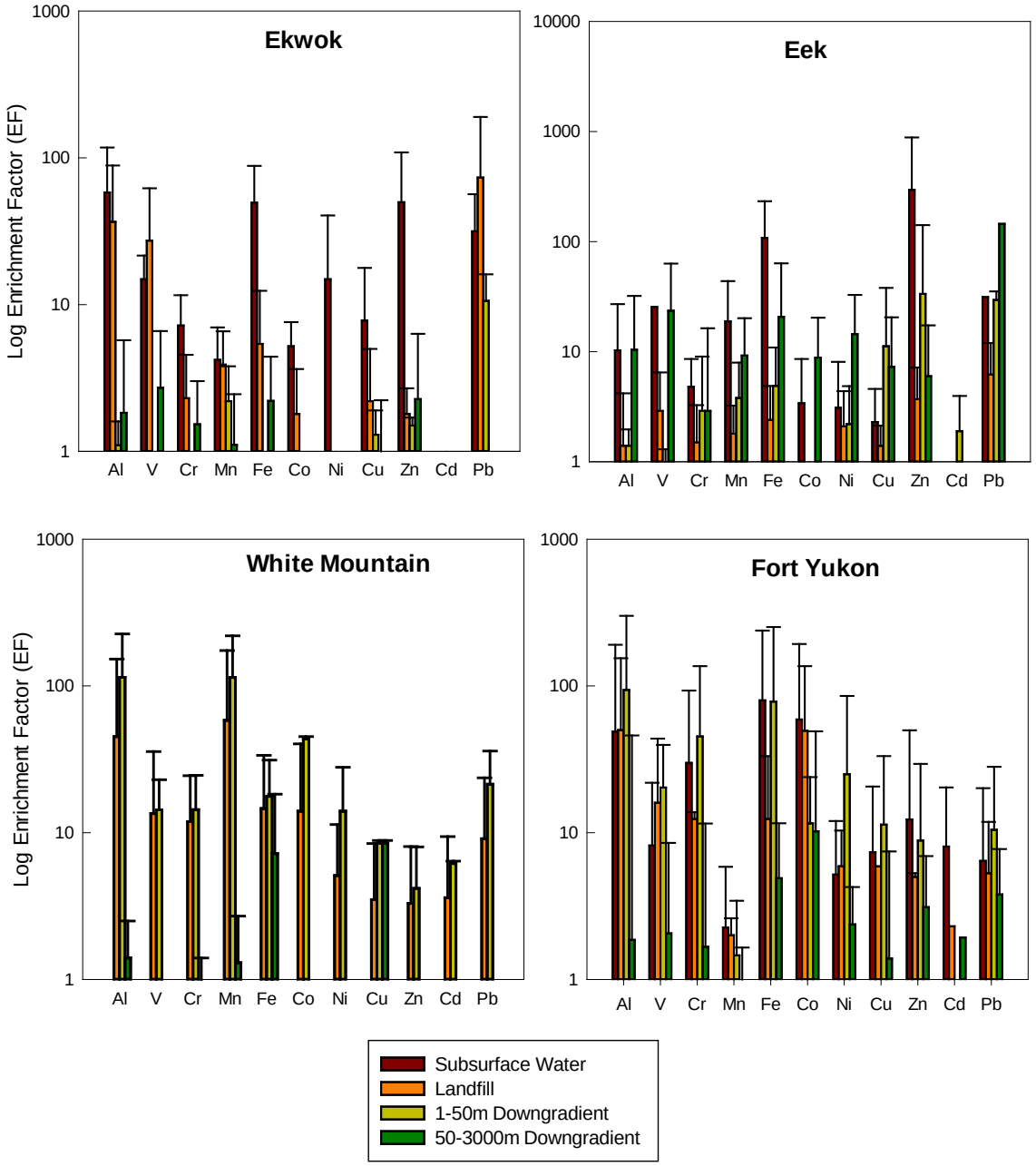

Figure II-2: Enrichment Factor of Total Heavy Metal Concentrations

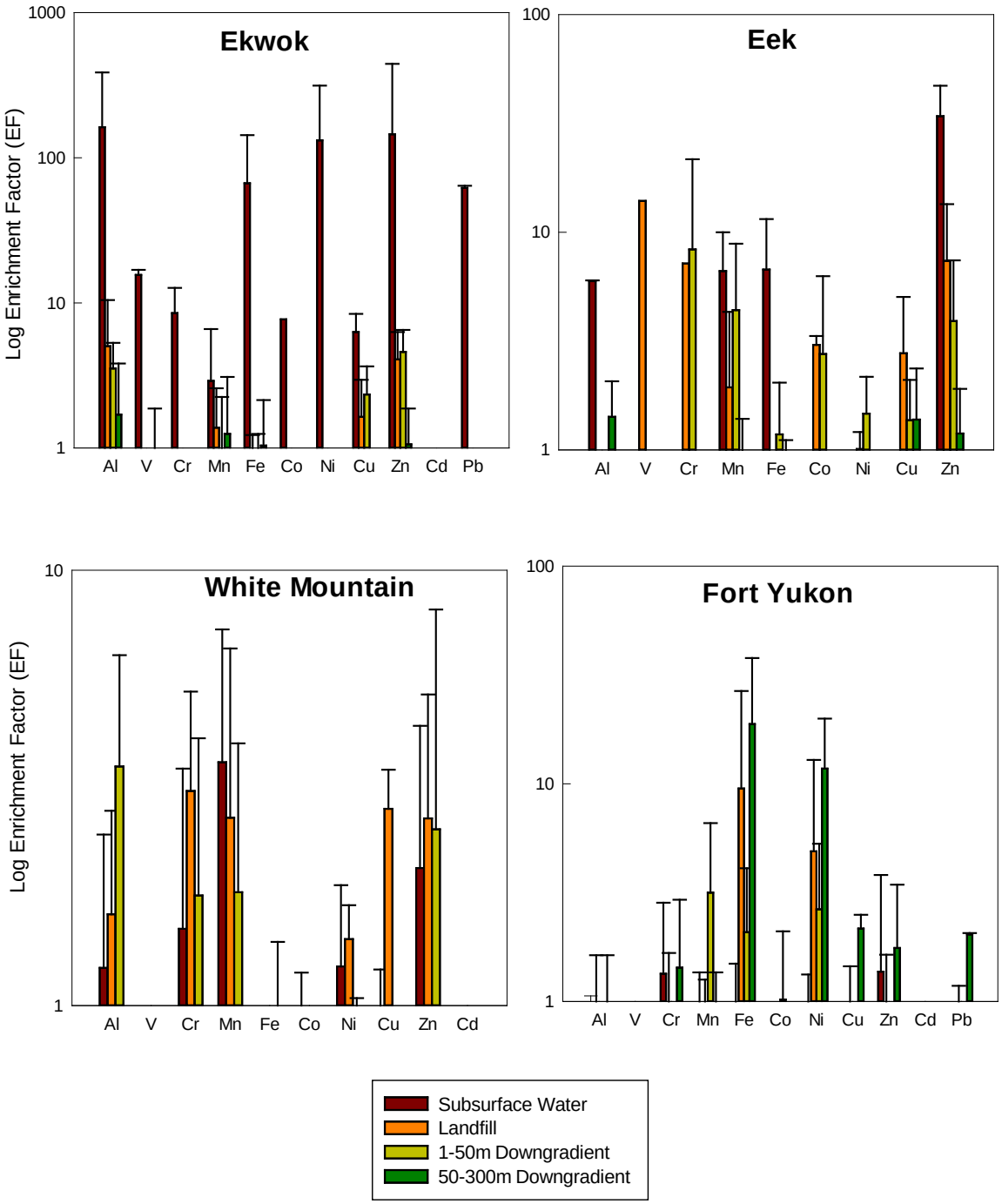

Figure II-3: Enrichment Factor of Dissolved Heavy Metal Concentrations

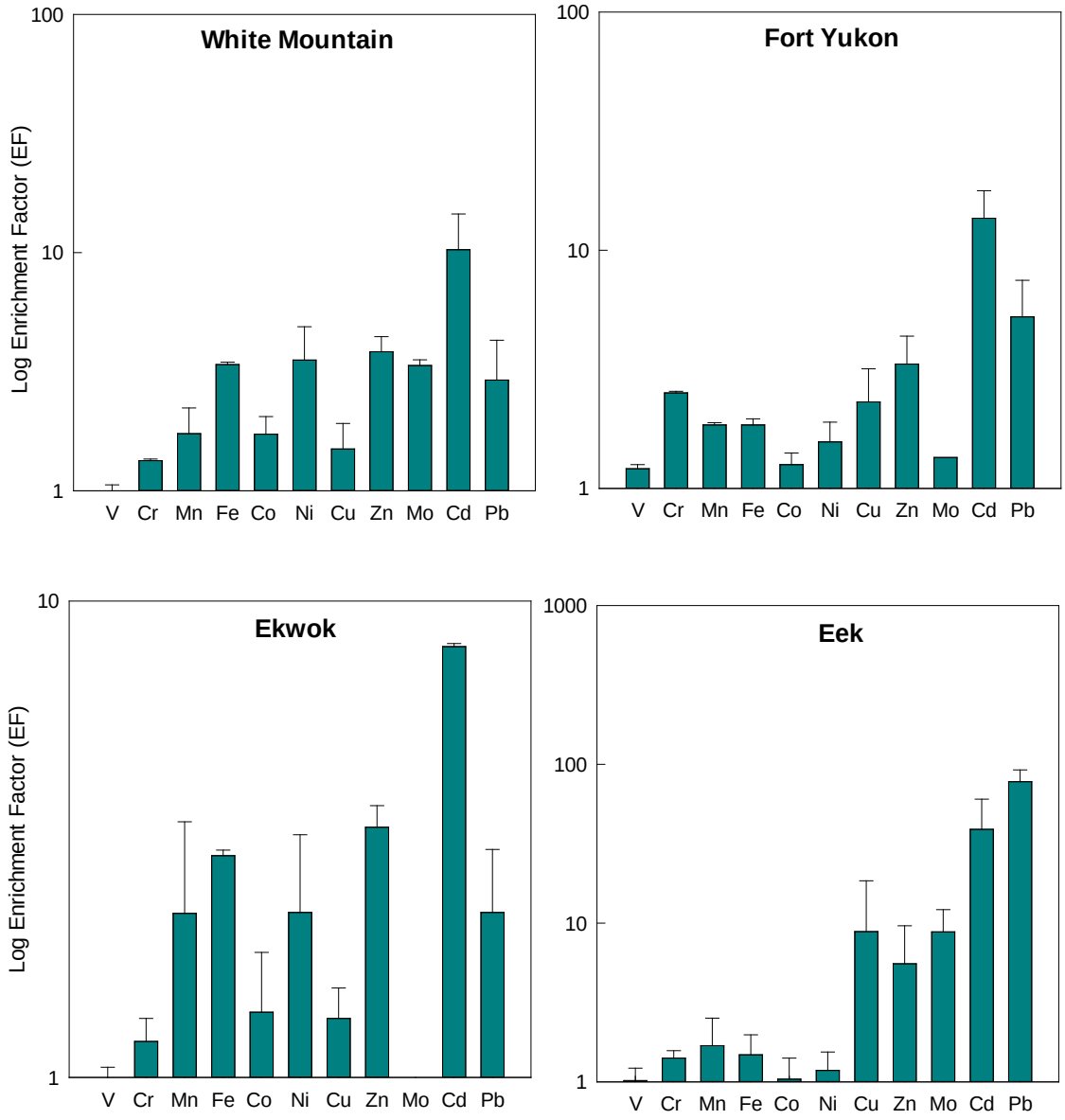

Figure II-4: Enrichment Factor of Soils Heavy Metal Concentrations

8. Tables

Table II-1: Samples collected at each sample locations over the duration of two years

Sample ID	Sample Locations	Ekwok	Eek	White Mountain	Fort Yukon
A	Landfill surface water	5	9	8	7
B	Surface water 1-50 meters down-gradient	6	5	5	9
C	Surface water 50-3,000 meters down-gradient	11	15	6	10
D	Subsurface water	11	4	0	10
E	Surface water control	9	7	4	6
aa	Landfill impacted soils	3	7	3	4
ab	Control soils	2	3	2	2

Table II-2: Five contaminant categories are established for the EFs (Sutherland 2000; Loska and Wiechula 2003)

EF = 2-5	Moderate enrichment
EF = 5-20	Significant enrichment
EF = 20-40	Very high enrichment
EF = > 40	Extremely high enrichment

Table II-3: Range and values of physiochemical characteristics for all surface and subsurface waters

Location	ID	pH (unit)	Temperature (^{0}C)	Conductivity (µS cm$^-$)	TSS (mg L$^-$)	TOC* (mg L$^-$)	$CaCO_3$ * (mg L$^-$)
Ekwok	A	6.4 - 7.7	5.2 - 19.5	194.2 - 282.4	670.3 - 4,247.0	42.4	37.5
	B	5.8 - 7.4	2.2 - 9.3	435 - 507.0	130.5 - 210.6	22.4	22.5
	C	6.3 - 7.5	1.9 - 11.3	14.6 - 228.6	7.5 - 30.3	4.0	26.7
	D	6.2 - 7.5	3.5 - 9.3	179.0 - 569.0	240.0 - 11,616.0	60.9	20.0
	E	7.2 - 7.8	1.1 - 11.1	18.6 - 228.6	4.5 - 5.1	3.5	20.0
Eek	A	6.4 - 7.6	0.2 - 12.0	185.8 - 567.4	73.3- 514.3	37.9	80.0
	B	6.4 - 7.7	0.2 - 13.9	77.0 - 130.4	137.5 - 550.0	13.1	120.0
	C	5.7 - 7.7	0.4 - 13.9	14.0 - 150.1	6.7 - 8.1	4.4	84.4
	D	6.8 - 10.3	n.a.	400.0 - 2,300	581.2 - 5,189.1	60.9	80.0
	E	6.3 - 7.7	0.7 - 13.9	17.8 - 136.7	8.1 - 12.1	7.0	40.0
White Mountain	A	7.3 - 8.2	4.7 - 21.6	200.2 - 2,200.0	185.1 - 1,700.3	45.2	131.4
	B	6.7 - 8.7	3.2 - 20.7	574.0 - 1,920.0	208.5- 710.1	56.2	186.7
	C	6.7 - 8.7	3.2 - 11.5	245.3 - 580.0	10.0 - 270.0	n.a	113.3
	E	7.8 - 8.1	2.3 - 13.4	65.2 - 136.5	8.7 - 10.0	4.2	40.0
Fort Yukon	A	6.8 - 8.6	5.2 - 21.5	178.0 - 1,855.0	50.0 - 1,400.3	13.9	432.0
	B	7.2 - 8.4	5.2 - 15.5	748.9 - 1,980.0	186.2 - 4,962.0	51.4	196.0
	C	7.8 - 8.6	12.8 - 21.3	22.0 - 214.6	5.7 - 50.0	8.8	100.0
	D	6.7 - 8.2	8.0 - 14.0	1,480.0 - 3,063.0	676.0 - 6,578.2	53.7	253.2
	E	6.8 - 8.6	13.0 - 18.9	19.0 - 526.7	70.0 - 171.4	9.7	90.0

where A represents landfill surface water, B surface water 1-50 meters down-gradient, C surface water 50-3,000 meters down-gradient, D subsurface water, E surface water controls, * samples only measured one time, and n.a. for not analyzed.

Table II-4: Average and values of soil physical parameters

Location	ID	pH (unit)	Moisture Content (wet %)	Sand (%)	Silt (%)	Clay (%)
Ekwok	aa	7.1 ± 0.3	35.1 ± 9.6	3.1	28.6	68.3
	ab	6.9 ± 0.1	36.2 ± 8.5	2.5	30.9	66.7
Eek	aa	6.0 ± 1.4	47.7 ± 1.2	2.3	19.4	78.3
	ab	5.1 ± 0.1	28.1 ± 1.2	0.1	13.6	86.3
White Mountain	aa	7.7 ± 0.2	31.9 ± 6.5	4.9	44.4	50.6
	ab	7.8 ± 0.1	22.9 ± 1.0	0.3	41.2	58.4
Fort Yukon	aa	8.7 ± 0.2	41.7 ± 3.8	2.9	27.0	70.1
	ab	7.3 ± 0.4	30.7 ± 2.8	2.1	19.6	78.3

where aa represents landfill impacted soil samples and ab control soil samples. For soil particle distribution standardized sieves were used with the size of 2 mm to 62 µm for sand, 62 to 3.9 µm for silt and < 3.9 µm for clay faction.

Table II-5: ICP-MS average metal concentrations and their representing standard deviations with 95% confidence levels of surface and subsurface waters

Location	ID	n	Al (ppm)	V (ppb)	Cr (ppb)	Mn (ppm)	Fe (ppm)	Co (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppm)	Cd (ppb)	Pb (ppb)
LOD			0.4	0.6	0.1	0.2	11.5	0.3	0.4	0.3	0.5	0.1	0.2
	A	4	8.4±1.7	44.6±7.0	13.7±16.3	1.1±2.7	4.9±10.7	8.6±13.8	11.5±17.7	32.5±72.9	0.09±0.2	0.2±0.2	11.6±20.8
	B	6	26.8±27.1	87.8±47.9	20.5±15.9	3.2±4.8	15.4±16.7	19.6±18.8	22.8±27.2	90.6±116.8	0.3±0.3	ND	29.1±27.9
	C	9	0.2±247.6	1.2±0.9	3.7±4.6	0.09±0.1	1.2±1.9	0.4±*	ND	1.8±1.4	0.07±0.2	0.2±*	1.6±1.9
Ekwok	D	13	30.8±37.2	27.8±23.7	36.8±38.9	0.8±0.5	90.8±90.2	14.6±15.5	207.8±547.8	75.0±59.5	5.5±10.0	0.3±0.2	11.4±10.7
	E	5	1.0+0.9	1.5+0.7	0.6+*	0.04+0.03	0.8+0.06	ND	ND	ND	0.04+0.03	ND	ND
	A	5	0.2±0.4	2.5±1.9	6.5±10.1	0.1±0.08	3.1±1.4	0.8±0.5	4.0±3.5	14.0±13.6	0.2±0.2	0.3±*	1.8±0.7
	B	12	0.8±0.6	1.7±1.0	6.1±11.2	0.3±0.2	12.3±27.9	1.1±0.5	6.3±7.0	53.8±116.9	0.6±1.5	0.6±0.5	5.5±6.9
Eek	C	6	0.1±0.09	1.0±0.9	0.8±0.5	0.1±0.1	0.9±0.8	1.0±0.3	1.4±0.3	3.4±1.4	0.01±0.01	0.1±*	0.9±*
	D	6	2.8±4.6	94.5±*	15.2±16.0	2.1±1.3	154.5±140.1	16.2±11.5	64.7±55.6	65.0±31.2	3.6±3.8	ND	29.0±*
	E	13	0.1±0.05	0.7±0.4	0.8±*	0.09± 0.03	1.3±0.7	0.4±*	2.2±2.1	2.4±0.8	0.01±0.01	ND	0.6±*
White	A	5	1.0±1.1	7.0±43.5	9.1±9.8	2.4±4.6	6.7±11.4	12.8±22.3	33.6±48.0	21.7±33.4	0.1±0.2	1.2±2.5	3.2±15.4
Mountain	B	7	5.2±5.5	17.4±4.8	11.1± 6.8	3.1±5.1	4.3±2.5	24.3±19.1	60.6±47.6	39.3±36.8	0.1±0.2	1.9±0.9	12.2±6.4
	C	6	3.2±2.4	5.1±*	7.6±2.7	0.3±0.4	21.8±0.1	1.9±*	32.0±24.8	4.8±*	0.08±0.03	ND	9.8±10.1
	E	4	0.2+0.2	1.2+0.3	0.9+0.6	0.08+0.1	9.0+15.2	0.7+0.6	3.9+2.9	3.7+1.3	0.03+0.01	0.2+0.02	1.1+0.7
Fort	A	6	0.3±0.5	3.1±4.0	0.6±0.4	2.4±2.1	10.6±13.7	10.4±11.9	34.4±22.4	14.3±7.3	0.4±0.9	0.4±0.3	12.8 ± 5.6
Yukon	B	9	15.1±39.3	13.0±27.5	40.7±65.6	2.6±3.0	1.2±36.5	20.4±26.7	352.1±722.7	57.3±62.8	0.2±0.3	3.1±0.4	17.0±15.8
	C	6	0.6±1.0	4.2±3.4	2.8±2.0	1.5±3.5	1.5±1.6	3.8±5.3	15.8±16.8	7.4±4.0	0.01±0.01	0.3±0.1	1.7±1.5
	D	16	13.7±22.6	40.2±21.7	131.6±294.9	3.2±2.6	284.4±567.0	28.8±21.8	194.4±186.2	94.0±103.8	2.6±3.2	8.4±10.1	23.4±16.2
	E	6	0.5±0.5	2.7±1.4	1.2±0.8	0.2±0.4	1.2±0.8	1.5±1.1	11.4±5.8	4.3±1.7	0.05±0.08	0.2±0.03	1.2±0.8

where A represents landfill surface water, B surface water 1-50 meters down-gradient from the landfill, C surface water 50-3,000 meters down-gradient from the landfill, D subsurface water, E surface water controls, ND for samples not detected, and * no standard deviation due to few detected samples.

Table II-6: Pearson correlation matrix of physicochemical characteristics and metals of surface and subsurface waters

	pH	Cond	Alk	TOC	TSS	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
pH	1															
Cond	-0.135	1														
Alk	0.292	0.144	1													
TOC	0.084	0.520	0.362	1												
TSS	-0.091	0.506	0.246	0.175	1											
Al	0.035	0.019	-0.090	0.203	-0.140	1										
V	-0.046	0.344	-0.182	-0.239	-0.072	0.986	1									
Cr	0.072	0.215	0.126	0.011	0.173	0.611	0.639	1								
Mn	0.086	0.141	0.152	-0.083	0.113	0.109	0.516	0.565	1							
Fe	0.120	0.212	0.142	-0.064	0.055	0.218	0.790	0.102	0.204	1						
Co	0.089	0.105	0.102	0.183	0.193	0.445	0.636	0.919	0.777	0.438	1					
Ni	0.021	0.184	0.047	0.048	0.003	0.064	0.256	0.569	0.964	0.397	0.852	1				
Cu	-0.006	0.266	0.006	0.137	0.306	0.500	0.841	0.682	0.138	0.305	0.609	0.096	1			
Zn	-0.027	-0.038	-0.175	0.119	0.005	0.047	0.726	0.398	0.010	0.152	0.740	-0.026	0.844	1		
Cd	0.107	0.330	0.234	0.402	0.160	0.511	0.782	0.942	0.650	0.559	0.921	0.737	0.237	0.075	1	
Pb	0.030	0.099	0.145	-0.071	0.297	0.969	0.979	0.626	0.458	0.561	0.599	0.261	0.610	0.191	0.676	1

*p = 0.05

Table II-7: ICP-MS average metal concentrations and their representing standard deviations with 95% confidence levels in landfill impacted soils and controls.

Location	ID	n	Al (kg kg^{-1})	V (mg kg^{-1})	Cr (mg kg^{-1})	Mn (mg kg^{-1})	Fe (kg kg^{-1})	Co (mg kg^{-1})	Ni (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Cd (mg kg^{-1})	Pb (mg kg^{-1})
LOD			1.0	1.5	0.7	0.7	80.0	0.8	0.1	0.3	0.2	0.6	0.4
Ekwok	aa	4	16.0±2.2	45.1±8.1	19.0±1.7	407.1±217.9	19.0±1.9	6.6±1.9	18.8±7.7	14.5±4.1	56.0±22.5	0.6±*	8.7±1.8
	ab	3	14.7±0.7	42.2±4.2	16.4±27.1	248.2±102.3	15.1±0.8	5.3±0.8	11.3±0.4	11.6±0.4	41.4±1.0	<LOD	5.3±1.0
Eek	aa	8	15.7±6.0	38.9±9.6	38.3±18.6	332.0±182.3	29.5±18.4	7.3±2.0	26.2±11.9	172.4±222.9	453.9±527.4	4.2±3.6	106.1±137.8
	ab	3	13.0±3.6	38.8±14.9	22.4±8.1	224.3±135.1	17.0±7.1	6.7±2.5	17.1±5.4	15.2±9.5	51.3±15.1	0.7±*	5.4±3.2
White	aa	3	15.2±5.1	38.2±11.5	20.6±6.9	522.8±94.4	19.5±5.7	7.7±1.4	27.1±2.2	15.2±3.3	58.7±12.4	0.5±*	13.0±2.8
Mountain	ab	3	10.7±0.8	27.0±2.3	14.6±1.5	381.7±19.8	14.3±0.5	5.7±0.1	24.7±2.0	13.1±0.9	47.3±1.2	<LOD	8.7±1.8
Fort	aa	4	10.3±1.5	40.1±3.4	20.4±6.6	249.8±46.1	15.2±1.2	6.0±0.6	20.6±3.6	18.4±8.9	72.6±20.3	0.6±0.3	11.2±5.4
Yukon	ab	3	9.2±1.4	36.2±1.3	14.6±1.5	171.8±3.0	13.2±1.1	5.3±0.2	14.2±0.7	8.4±0.4	52.0±2.2	<LOD	6.0±0.1

where aa - Soil impacted samples, ab - Soil control samples, < LOD - below detection limit and*no standard deviation due to few detected samples

Table II-8: Pearson correlation matrix of heavy metals in landfill impacted soils

	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	pH	sand	silt	clay
Al	1														
V	0.469	1													
Cr	0.677	0.128	1												
Mn	0.498	-0.173	0.260	1											
Fe	0.758	0.033	0.882	0.452	1										
Co	0.531	-0.136	0.470	0.795	0.656	1									
Ni	0.445	-0.388	0.657	0.639	0.780	0.743	1								
Cu	0.592	-0.139	0.881	0.301	0.927	0.435	0.773	1							
Zn	0.581	-0.117	0.902	0.322	0.925	0.430	0.742	0.982	1						
Cd	0.970	-0.042	0.935	0.911	0.995	0.769	0.974	0.998	0.986	1					
Pb	0.576	-0.076	0.916	0.365	0.856	0.413	0.675	0.892	0.949	0.873	1				
pH	-0.190	-0.181	-0.110	0.260	-0.012	0.131	0.288	0.028	-0.002	-0.210	0.011	1			
sand	0.063	0.017	-0.400	0.461	-0.226	0.163	0.063	-0.345	-0.359	-0.615	-0.328	0.378	1		
silt	-0.075	0.080	-0.545	0.371	-0.366	0.026	-0.069	-0.464	-0.482	-0.615	-0.450	0.560	0.934	1	
clay	0.066	-0.076	0.537	-0.379	0.358	-0.036	0.061	0.458	0.476	0.615	0.443	-0.550	-0.942	-1.00	1

*p = 0.05

Chapter III

Partitioning and Transport Behavior of Pathogen Indicator Organisms in Cold Region Waste Sites

Abstract

Community health in rural Alaska is dependent upon the provision of clean, safe drinking water. Rural Alaska communities, especially those underlain by permafrost, often have freshwater resources that are particularly vulnerable to impacts from nearby waste facilities. Frequent exposure of rural communities to pathogenic contaminants is attributed to inadequate sanitation facilities, direct discharge of untreated human waste and wastewater, and close contact with human waste. Identifying specific point sources of fecal contamination is critical to preventing exposure, mitigating human and environmental health risks, and for developing management plans to protect freshwater resources. This study investigated the connection between rural waste facilities and the transmission of pathogenic organisms into nearby water resources using *Escherichia coli (E. coli)* and *Enterococcus sp*. as indicator organisms. In addition, the viability of *E. coli* and *Enterococcus sp.* in cold climate regions was evaluated, and the partitioning behavior of both organisms in meltwater was examined. The results reveal that *E. coli* and *Enterococcus sp.* tend to preferentially attach and migrate with soil particles in surface waters, and are frequently transported offsite during snowmelt runoff. *Enterococcus sp.* was observed to have higher and more sustained viability in cold environmental conditions, and therefore may be a more suitable indicator organism compared to *E. coli* for cold climate regions. Waste sites in rural communities were found to transmit *E. coli* and *Enterococcus sp*. into nearby water resources. *E. coli* and *Enterococcus sp*. were found in surface waters and soils in the concentration range of 0.7 - 3.5 mean Log MPN/100 mL H_2O. All microbial samples indicated strong site-specific variability.

[1] Mutter, E.A., Schnabel, W., Duddleston K.N. Fairbanks 2014. Partitioning and Transport Behavior of Pathogen Indicator Organisms in Cold Region Waste Sites. Prepared for submission in Cold Region Science and Technology.

1. Introduction

Alaska is the largest state in the U.S., and 40% of the state's population resides in more than 300 rural communities (BIA, 2003; Patterson et al., 2012). Because of Alaska's size, its rural communities are located across diverse geographic areas and climate zones, and most of these communities are not connected by a road system. These factors, combined with socioeconomic challenges resulting from a small tax base, create challenges for solid waste and wastewater management (Black and Logan, 2000; Herdman, 1994; Patterson et al., 2012; Puchtler, 1978). Historically, many rural Alaska waste facilities have had minimal site control, irregular maintenance, little or no waste treatment, inadequate monitoring of leachate generation to nearby water resources, and have been subjected to seasonal flooding (ANTHC, 2007; Crum, 1993; Friedman et al., 1999; Patterson et al., 2012).

Intentional or unintentional discharges waste from inadequately managed waste facilities can lead to transmission of pathogens to surface water resources, posing a risk to human and environmental health (Smith and Low, 1996; Zender et al., 2003). Among Alaska Natives, frequent exposure to pathogenic bacteria is implicated in reports of hepatitis A and B, bronchitis, impetigo, rashes, pneumonia, and endemic enteric meningitis. In particular, young children and elder residents are affected (ANTHC, 2009; DHSS, 2005; Hennessy, 2008). Disease outbreaks have been attributed to conditions such as insufficient drinking water and wastewater services in 35% of communities and to the use and handling of five-gallon in-home wastewater receptacles known as "honey buckets" (ANTHC, 2009; Hennessy, 2008). Spillage of human waste from honey buckets during transport to disposal sites has been demonstrated to promote dispersion of waste-related organisms across community roads and boardwalks (ANSC, 2004; Chambers et al., 2008; EPA, 1994). In addition, at least 30% of the rural communities dispose of human waste together with solid waste directly into tundra ponds, on ground underlain by permafrost, or on saturated tundra (Patterson et al., 2012; Zender et al., 2003), which poses an additional pathogen risk. Finally, studies have identified an association between storm water events and the outbreak of waterborne pathogenic organisms in human population (Currieo et al., 2001; Rose et al., 2001).

For rural Alaska communities, pollution from fecal contamination is a critical health issue, given the proximity of many waste disposal sites to community centers as well as their food and drinking water resources (Patterson et al., 2012). For example, a source-water assessment in the Kuskokwim Delta region rated the majority of public water systems employing surface water

sources as “highly” or “very highly” vulnerable to bacterial/viral impacts (ADEC, 2008). A different study conducted to evaluate the presence of pathogen indicator organisms in a rural community setting illustrated the wide dispersion of pathogen indicators across the rural landscape during and after the spring melt due to the prevalence of standing water (Chambers et al., 2008). In Canada, a study performed to assess microbial load and rain runoff events established a correlation between increase of runoff and cryotolerant coliform (e.g., *E.coli*) load (Hyland et al., 2003). A study by Adhikari et al. (2007) on fecal coliform survivability in frozen soils demonstrated that fecal coliform bacteria can survive outside a host for prolonged periods under cold conditions, and (Wang and Marchin, 1996) conducted a study in temperate regions suggesting that pathogens released from raw sewage can survive in the soils and surface water for a year or longer. Payment et al. (2003) found that, despite research efforts, very little is known about the degree of freshwater contamination and the potential for transmitting disease-causing bacteria and other microorganisms in cold climate regions, due to the lack of understanding regarding the persistence of different microbial types in the environment (Hrishikesh et al., 2007; Miettinen et al., 2001; Okoh et al., 2007).

It is a challenging task to elucidate the spatial and temporal transmission of source-specific pathogenic organisms into freshwater resources near rural communities. In cold climate regions, the transport of pathogenic organisms within a community is affected by the waste disposal practices of individuals (Patterson et al., 2012), the complex hydrologic pathways associated with permafrost-affected soils, and the tolerance of microbial organisms to long periods of subzero temperatures (Balaban et al., 2004). Arctic and subarctic regions are affected by permafrost, which consists of two physically distinct compartments: the active layer (which thaws during summer) and the permafrost layer (perennially frozen, often ice-rich ground). Due to the limited thaw depth of the active layer and the restricted permeability of permafrost, the transport of stormwater and snowmelt is often restricted to the surface (Alloway and Ayres, 1997; Lunde and Young, 2005; Maidment, 1993). Thus, seasonal events such as snowmelt and rain can have a significant effect on the transport of free-living or particle-bound microbes through the surface water.

Previous studies have demonstrated that microbes entrained within or lying underneath snow are often kept viable by the cold (Adhikari et al., 2007; Price and and Sowers, 2004), thus indicating that viable pathogens may reach higher concentrations in meltwater compared to concentrations

in rainwater runoff. Indeed, a study describing an Anchorage, AK stream reported springtime fecal coliform concentrations that were orders of magnitude higher than concentrations observed during the remainder of the year (Schnabel et al., 2010). Other studies have shown that pathogenic indicator bacteria found in surface waters tend to associate with particles (Characklis et al., 2005; Fries et al., 2006), and that particulate-attached microbes can form microbial reservoirs in stream beds that become re-suspended during periods of high flow (Jamieson et al., 2003). Thus, the snowmelt runoff events at rural Alaska waste sites may carry particularly high loads of pathogenic organisms and deposit them into surrounding surface waters.

The objectives of this study were to evaluate the source-specific potential to transmit pathogenic organisms into freshwater resources near rural Alaska communities, and to investigate the transport pathways of pathogenic organisms during seasonal precipitation events. As a measure of fecal contamination, *Escherichia coli (E. coli, or EC*) and *Enterococcus sp.* (*ENT)* microbial indicator organisms (MIO) were enumerated in surface waters and soil samples collected in the vicinity of five rural Alaska landfills, two sewage lagoons, and their natural drainage areas. The direct counts of MIO were used to evaluate the temporal and spatial distribution of indicator organisms with respect to seasonal precipitation events and differences in arctic and subarctic environmental settings. In addition, a snowmelt lysimeter facility on the University of Alaska Fairbanks campus was employed to help illuminate MIO survivability, partitioning, and transport processes associated with winter storage and snowmelt runoff in a controlled setting. The lysimeter results were utilized to help inform and interpret the MIO data collected in the field. Rural Alaska waste facility conditions are illustrated in Figure 1.

2. Study Sites

2.1 Lysimeter Experiment

A freestanding lysimeter was constructed at the University of Alaska Fairbanks Experiment Farm based upon a design reported by (Kattelmann, 1984). The lysimeter encompassed a surface area of 8 m^2, and was framed with 6 mm plastic sheeting (clear visqueen) fixed to the bottom and sides. An approximate 2% downhill slope was constructed to capture all of the moisture emerging from the snowpack either through infiltration or runoff. Rain gutters were installed to facilitate water collection. The lysimeter contained a homogenized mixture of 33.3 kg of fecal coliform

source (manure) placed on top of a designed soil matrix, composed of 6.4 cm of silt underlain by a 5.1 cm sand. The sand underlying the silt was intended to serve as a drainage layer. The manure mixture consisted of 23% muskox manure obtained from Robert G. White Large Animal Research Station at UAF, 73% cattle manure obtained from the UAF Palmer Research & Extension Center, and 4% reindeer manure obtained at the Fairbanks Experiment Farm. The lysimeter was completed in October 2008, and allowed to accumulate snow until the subsequent snowmelt in April 2009. Naturally accumulated snowfall of 55.9 cm was measured immediately prior to the 2009 snowmelt. The constructed lysimeter experiment setting is illustrated in Figure 2.

2.2 Rural Communities

In order to evaluate the prevalence of MIO associated with rural Alaska waste facilities, soil and water samples were obtained proximal to the landfills and sewage lagoons in five separate communities. These arctic and subarctic facilities encompass a variety of environmental settings representing the presence/absence of permafrost, and the presence/absence of tundra ponds. The waste facilities of each community are located relatively close to the community center and are impacted by seasonal snowmelt and rainwater runoff. Annual temperature and precipitation data for the sampling locations are reported in Table 1.

Ekwok is a community of 130 residents, located along the Nushagak River, 69 km northeast of Dillingham and 302 km southwest of Anchorage (Census, Bureau, 2010). The community is situated in a non-permafrost area, and most residential homes are equipped with in-home plumbing system for waste and drinking water. Drinking water is obtained from shallow groundwater wells and wastewater discharge occurs through a sanitation systems, which includes piped a septic system connected to a sewage lift station or a flush/haul system (DHHS, 1992). Sewage collection and wastewater hauling services are provided to the community weekly. The approximately 30 year's old landfill is constructed belowground on excavated tundra approximately 2.4 km northeast upland of the village. The landfill is 0.4 km^2 in size and 3.0-4.5 m deep, creating a 22% slope toward the lowland area. The constructed sewage lagoon, which is lined with sand material and heavily overgrown with vegetation, is located 500 m from the

community and approximately 800 m from the Nushagak River. The community is on a pump-hauling system for sewage and wastewater.

Eek is a community of 208 residents, located on the south bank of the Eek River, 19 km east of the mouth of the Kuskokwim River and approximately 56 km south of Bethel in the Yukon-Kuskokwim Delta (Census, Bureau, 2010). The community is situated in discontinuous permafrost region, comprising saturated tundra and many tundra ponds with only a few meters of elevation marking the boundaries of major drainages (ADEC, 2011). The community derives water from Eek River for its primary domestic water supply source, which is treated and stored at the washeteria. Rain entrapment systems and ice melt are utilized for secondary portable drinking water sources. Only the community school, school housing and washeteria are connected with in-home plumbing for water and wastewater. Individual households haul their drinking water from the washeteria or from traditional drinking water sources. Household wastewater is discharged directly onto the tundra or into the nearby sewage lagoon. Honey buckets are used to transport human waste and discharged into the traditional sewage lagoon. The sample locations are an approximately 30-year-old ponded landfill and a honey bucket lagoon located adjacent to the landfill, both 0.8 km^2 in size. The two waste sites are located less than 1.6 km from the community. Based on a reconnaissance of the waste sites, the hydrologic system is complex and is influenced by tides, permafrost, and surface water. Saturated tundra ground with standing water is encountered around the landfill and honey bucket lagoon year-round.

White Mountain, a community of 224 residents, is located 100 km east of Nome on the Seward Peninsula on the west bank of Fish River (Census, Bureau, 2010). White Mountain is distinguished with shallow permafrost and wet tundra; however, south-facing slopes were identified with the presence of discontinuous permafrost below the vegetative layer (Chambers et al., 2007). The community obtains its treated domestic water supply from groundwater wells located in the village. The majority of the community is connected to the piped water and sewer system. Nonetheless, 25% of residents still haul honey buckets for human waste and wastewater. The approximately 30-year-old aboveground landfill is located in an upland area approximately 400 m east of the village and north of the river. The landfill is 0.6 km^2 in size and rises approximately 4.5 m to create an 18% slope east/southeast toward a lowland area. Standing water occurs during snowmelt and rain events forming a natural drainage area to the east/southeast of the landfill.

Fort Yukon, a community of 600 residents, is located at the confluence of the Yukon River and the Porcupine River, approximately 233 km northeast of Fairbanks (Census, Bureau, 2010). Fort Yukon is situated in the low-lying Yukon Flats region, which is characterized by vast areas of forested wetlands and bogs underlined by discontinuous permafrost. The community obtains its domestic water supply from two groundwater wells located in the village. The domestic water is tank-stored and treated before being supplied through a piped system to residents' homes. Residential homes are provided with piped sewage systems connected to lift stations and pumped to a newly constructed, lined sewage lagoon located approximately 2.4 km east of town. An approximately 30-year-old aboveground landfill is located in an upland area 2.4 km from the community. The 0.2 km^2 landfill is situated along the edge of an old riverbank 8-15 m higher than the lowland area, creating a 32% slope towards the lowland. At the time of this study, the landfill that had been used by the community was closed and covered with gravel, while a new permitted landfill was under construction. In the meantime, solid waste material was being placed on the outside border of the closed landfill and managed primarily through aboveground burning. The close-capped sewage lagoon is located adjacent to the landfill.

Allakaket is a community of 190 residents, located approximately 306 km northwest of Fairbanks, on the south bank of the Koyukuk River (Census, Bureau, 2010). The land is characterized by shallow permafrost and tundra ground. Domestic drinking water is supplied by treated Koyukuk River water at the community washeteria (Patterson et al., 2012). Only the community school, school housing and washeteria are connected to in-home pluming for water and wastewater. Individual households haul drinking water from the washeteria or from traditional drinking water resources. Household wastewater is discharged directly onto the tundra or into local tundra ponds. Honey buckets and pit privies are used for human waste. The approximately 10-year-old aboveground landfill is located in an upland area along a ridge approximately 1.6 km south from the old village site, and approximately 1.2 km from the new village site. The landfill is 0.7 km^2 in size. A natural drainage area is formed by an approximate 4% slope to the south. Rural Alaska communities and representative region is illustrated in Figure 3.

3. Methods and Materials

3.1 Snowmelt Lysimeter MIO Partitioning Study

Discharge from the snowmelt lysimeter was collected daily throughout the April 2009 snowmelt event. Daily runoff was quantified in a graduated cylinder following initial measurements of pH, electrical conductivity, and temperature via Combo Hanna meter (Hanna Instruments). Subsamples of the daily accumulated meltwater were collected in sterile 200 mL HDPE bottles for analysis of total suspended solids (TSS) and MIO. Total suspended solids were determined gravimetrically using 0.7 μm glass fiber filters (GC-C, Whatman). The method described by Fries et al. (2006) for MIO analysis was employed to discriminate between particle-bound and dissociated microbes. Subsamples (50 mL) of collected meltwater were centrifuged (Beckman Coulter, Allegra 25 R) at 500 × *g* for 10 minutes at room temperature. The centrifugation velocity was chosen to ensure particle separation based on settling velocity; based on the premise that particle-bound organisms will settle to the centrifuge bottom (Bratbak and Dundas, 1984; USFDS, 2003). The top volume was considered to contain only dissociated microbes or free-living microbes in water, while the lower portion of the centrifuge tube was considered to contain both particle-bound and dissociated microbes. Settled particles were often visible on the bottom of the centrifuge tubes and required careful separation from the top 35 mL portion to avoid re-suspension. The 35 mL top volume (dissociated fraction) and 15 mL bottom volume (particle-bound fraction) were carefully removed using a 50 mL pipette, redistributed into 100 mL sterile bottles containing thiosulfate, and diluted with sterile water to a total volume of 100 mL. Enumeration of microbial samples was performed using Colilert® for *EC* and Enterolert® for *ENT* (Idexx Laboratories, Westbrook, ME), following an EPA-approved most probable number (MPN) method supplied by the manufacturer. The 100 mL meltwater samples were incubated at 35°C for *EC* and 41°C for *ENT* for 24 to 28 hours. A 6-watt, 365 nm UV light was used to identify the positive wells for enumeration.

3.2 Microbial Viability

For the microbial survivability study, 0.4 g of muskox manure, 0.6 g of caribou manure, and 0.5 g of cattle manure were mixed together. The subsamples were submerged in 200 mL of sterile water and thoroughly mixed. A ten-step dilution series of 50, 40, 30, and 20 mL was performed

and brought to 100 mL with sterile water. Diluted manure samples were enumerated and incubated for *EC* and *ENT* using the Idexx MPN method. Manure water content was verified by weight difference between wet and oven-dried manure at 110°C for 24 hours. For the microbial survivability study, 10 manure subsamples were frozen at -40°C for 6 months. Manure samples were gently thawed for 6-8 hours and placed on a shaker for 10 minutes to allow complete mixing. The same dilution series, incubation, and enumeration methods for *ENT* and *EC* bacteria were performed as described above.

3.3 Rural Community Sample Collection and Analysis

On two consecutive days in spring 2010, fall 2010, spring 2011, and fall 2011, snowmelt and rainwater runoff along with soils were collected in sterile 200 mL HDPE bottles near the five rural community landfills and two sewage lagoons. Sampling efforts were limited at Ekwok after a new trench was constructed at the landfill in fall 2010, at Eek due to frozen ground and surface water in spring 2010 and fall 2010, and at Fort Yukon because of the closed and covered landfill. At White Mountain, surface water and soil were only obtained in spring 2010 and 2011; in Allakaket surface water and soil were obtained in June 2010 and August 2011. The same sampling procedure was utilized throughout the sampling events to ensure consistency throughout the study. Waste leachate surface water was collected according to the observed hydrologic pathways at the landfills, 1-50 m down-gradient, 50-3,000 m down-gradient, and 1-50 m up-gradient from each landfill. Raw sewage water samples were collected from a honey bucket and a constructed sewage lagoon, along with samples collected 1-50 m down-gradient of a new constructed sewage lagoon. Water pH, electrical conductivity, and temperature were measured *in situ* using a YSI Professional Plus or Combo Hanna meter. Approximately 100 g of soil samples were obtained from the soil organic and mineral layer (depth of 30 cm) for MIO analysis, pH analysis, and determination of water content. MIO analysis was performed either at the University of Alaska Anchorage, Applied Science Engineering and Technology (ASET) or University of Alaska Fairbanks, Water and Environmental Research Center (WERC) laboratory facilities within 12 hours of collection. Surface water samples were redistributed into 100 mL sterile bottles containing thiosulfate, and soil samples were thoroughly mixed to obtain the best representative distribution of microbial indictor load, and dissolved in 100 mL of sterile water.

Enumeration and incubation of microbial samples is described in Section 3.2. A determination of TSS was made using the method described in Section 3.1. Soil pH was measured in a 1:2.5 (v/v) ratio of water and soil suspension with a digital pH meter following the method procedure of Radojevic and Bashkin (1999). Control soil and surface water samples were assembled from undisturbed sites at each location. Total soil water content was verified by weight difference between wet soils and oven-dried soils at 110°C for 24 hours. Standardized sieves of < 2.36 mm for sand, < 2.00 mm for silt, and 149 μm for clay was used to determine soil particle distribution. The sample numbers obtained from each location and sample site are listed in Table 2.

4. Results and Discussion

4.1.1 MIO Survivability

The concentration of *EC* in a manure mixture decreased by approximately four orders of magnitude when stored at -40°C for a six month period (Figure 4), whereas the concentration of *ENT* decreased by approximately one order of magnitude over the same period. Thus, this result constitutes one line of evidence indicating that *ENT* may be more persistent in a cold environment than EC, and therefore may be a more appropriate indicator organism compared to *EC* for use in rural Alaska.

4.1.2 MIO Partitioning and Viability Results

Springtime meltwater was collected from the lysimeter to evaluate *EC* and *ENT* viability and partitioning behavior. Samples were collected daily throughout the month of April 2009. The meltwater pH ranged from 7.0-8.5 units; temperature ranged from 0.6-15.5°C; specific conductivity ranged from 63.4-96.0 μS/cm; and TSS ranged from 31.8-482.0 mg/L (Table 3).

The particle bound MIO concentration in the daily accumulation of lysimeter meltwater exceeded the dissociated MIO concentration in all samples collected throughout April, 2009 (Figure 5). In some instances, the particle-bound load was found to be approximately two orders of magnitude higher than the dissociated load. In most instances, however, the particle bound load was less than one order of magnitude greater than the dissociated load. Plotting the total daily lysimeter meltwater MIO load against the TSS load showed that increased TSS loading was associated in

some fashion to increased MIO loading, although the data did not conform particularly well to the logarithmic curve used to model the relationship (*ENT* $r^2 = 0.65$; *EC* $r^2 = 0.40$; Figure 6).

The purpose of the lysimeter study was not to specifically define the numeric relationship between TSS and MIO, but rather to confirm that such a relationship exits in snowmelt. In previous studies, Characklis et al. (2005) and Fries et al. (2006) demonstrated that pathogenic indicator bacteria found in surface water tend to associate with particles. This study indicated that snowmelt is similar to other surface waters with respect to microbial partitioning. Thus, mitigating the TSS load in meltwaters may help to reduce the flux of MIO in the runoff water. However, since at least some fraction of the MIO observed in this study was not particle-bound, TSS-mitigation measures would not be expected to contain all of the MIO. Moreover, the tendency of microbes to associate with particulates may have other relevant consequences as well. For instance, microbes associated with particles have been shown to survive longer in natural waters (Howell et al., 1996). Therefore, preferential partitioning of MIO to particulates in snowmelt may impact the length of time these organisms remain a threat to public health (Characklis et al., 2005).

4.2 *Physiochemical Characteristics of Surface Waters – Rural Community Study*

The pH of leachate-impacted surface waters ranged from 6.1-8.4 (Table 3). The pH values of landfill impacted surface water samples collected directly offsite the landfill (B) from Ekwok and in areas further away (50-3,000 m) from landfill in Eek (C) are lower than any specific sampling sites. (A, B, or C) observed in White Mountain and Fort Yukon. Location These (B) in Ekwok and location (C) in Eek are situated in lowland areas with poorly drained organic rich soils and peat, which have a high abundance of humic acid, that lower the pH values. The higher pH value for White Mountain, Fort Yukon and Allakaket landfills reflect the occurrence of limestone in these locations. The wide range of water temperature variability is related to the different sampling events performed from spring to freeze-back in early fall.

Higher conductivity and TSS concentrations tended to be associated with the samples collected at the landfills (location A), landfill adjacent drainage areas (location B), and sewage lagoon drainage areas (location E) compared to the control areas (Table 3). The electrical conductivity of

waters impacted by waste ranged between 77.0 and 3,063.0 μS/cm. This wide variability may have been associated with dilution from rain and snowmelt water, or concentration due to evaporation during the dry season. Additionally, large variability was observed within one location during a single sampling event, indicating a high degree of variability and limited mixing within a single landfill (Table 3). Total suspended solids were only measured once throughout the sampling events. Total suspended solids in the landfills and areas directly adjacent to the landfills were approximately 100 times higher than in areas further away from landfills (50-3,000 m), and approximately 10 times higher than at control sites. The low TSS concentrations observed at most of the control sites (<10 mg/L) were similar to the TSS commonly found in rainwater (Maidment, 1993).

4.3 Physiochemical Characteristics of Soils

The pH of all soil samples collected from the organic and mineral layer (0-30 cm in depth) ranged from 5.1-8.6, with higher values in soils from White Mountain, Fort Yukon, and Allakaket (Table 4). The pH of control soils was slightly lower than that of the landfill-affected soils. The control soil at Eek was collected from saturated tundra ground composed of poorly drained organic-rich tundra soil, which generally has a higher abundance of humic acid and lower pH (Ping et al., 2008). The pH of soil and the soil solution are critical for microbial growth, activity, and mobility, and individual organisms depend on a tolerable range. The waste impacted soils with the pH ranged from 5.1-8.6 provides suitable habitat for *EC* and *ENT*, which are both facultative anaerobic organisms with a wide range of pH (3.5-10.0) tolerance (Balaban et al., 2004; Miettinen et al., 2001). The predominant particle size in landfill-impacted and control samples was clay and silt (Table 4). Soil structure and texture are also important factors influencing the transport of water, air, nutrient, and microorganisms (Maier et al., 2009). Given the fine texture of the landfill-impacted and control soils, they are assumed to provide supportive habitats for microbial growth due to their water and nutrient retention capacity, as well as their ability to provide microbial attachment sites (Characklis et al., 2005; Fries et al., 2006). However, further analysis of the relationship between soil characteristics and microbial loading was not within the scope of this study.

4.4 Source-Specific MIO Study

A thorough examination of *EC* and *ENT* enumerated in soils and surface waters proximal to the waste sites reveals a number of trends (Table 5). First, the soil samples collected from the waste sites contained significantly higher concentrations of *EC* and *ENT* than did the control soils in every instance. Given that MIO tend to associate with soil particles (as demonstrated by the lysimeter study as well as previous research findings), this indicates a potential source (waste site soils) and mechanism (offsite migration of particle-laden water) for mobilization of MIO into the surrounding waters. Second, the MIO concentrations in surface waters from the landfills (and sewage lagoons) were significantly higher than the MIO concentrations in the control waters in every instance. Again, this result is not surprising, but does support the notion that water associated with the landfill can serve as a source of pathogens to the surrounding waters. Third, the surface waters directly adjacent to the landfills were not always significantly different from the MIO concentrations within the landfills themselves. Thus, in some instances at least, there was a clear pattern of MIO migration into the surrounding waters. Finally, there was a general downward trend in MIO concentrations associated with increased distance from the landfills.

The *EC* and *ENT* concentrations in surface water within the landfill footprints ranged between 1.5-3.0 and 2.1-3.0 mean Log MPN/100 mL H_2O, respectively, while the concentrations in offsite locations within 50 m of the footprint ranged from 0.7-3.2 (*EC*) and 0.9-3.0 (*ENT*) mean Log MPN/100 mL H_2O (Table 5). The constructed sewage lagoon and honey bucket lagoon surface water *EC* and *ENT* concentrations ranged from 2.4-3.4 and 2.9-3.4 mean Log MPN/100 mL H_2O, respectively. We did find it notable that no significant statistical difference was observed between the landfill and the sewage lagoon surface waters with respect to *EC* concentrations in Eek and *ENT* concentrations in Ekwok (Table 5). However, this observation is tempered to some extent by the limitations of the analytical test. In both cases, the MIO concentrations in numerous samples were found to be higher than the quantifiable range offered by the test, thus the finding of no significant difference is not strongly supported.

This study did not identify demonstrable differences in soil or water MIO concentrations based upon environmental settings such as frozen/unfrozen soils or wet/dry soil conditions. While the environmental setting potentially influenced the observed MIO concentrations, other variables such as seasonality were important as well. For instance, a higher volume of water runoff was

observed during snowmelt runoff when ground was still frozen and infiltration was limited, resulting in higher *EC* and *ENT* concentrations at Eek (ponded landfill in saturated tundra ground underlain by discontinuous permafrost) and Allakaket (newly constructed landfill underlain by permafrost), compared with Ekwok (belowground landfill underlain by discontinuous permafrost) and White Mountain and Fort Yukon (aboveground landfill and permafrost).

A significant relationship was found to exist between MIO for waste-impacted surface waters and TSS (Table 6). This agrees with the findings in the lysimeter component of this study, supporting the notion that sorption to particulates is an important factor in the mobilization of cold region microbes. With respect to soils, *EC* concentrations were found to be correlated to soil moisture as well as pH, while *ENT* were found to be correlated to soil moisture and soil type (Table 7). These findings merit further study.

5. Conclusions

This study was segregated into two components intended to evaluate the offsite migration of microbes from rural Alaska landfills. The first component was a controlled snowmelt lysimeter study demonstrating that MIO in snowmelt tend to preferentially associate with particulates in surface flows. This finding suggests that rural communities could potentially limit offsite migration of microbial contaminants by controlling snowmelt and rainwater runoff with berms, and/or creating vegetative buffer areas to capture particulates. The lysimeter study also showed that *ENT* survived cold storage in the field and laboratory in greater numbers than did *EC* bacteria, thus indicating that *ENT* may serve as a more robust indicator organism in Alaskan environmental conditions.

The second component of the study was an evaluation of MIO concentrations in and around five rural Alaska landfills. The results also confirm the suggestion by Adhikari et al. (2007) that, due to the ability of fecal bacteria to survive long periods of storage in subzero temperatures, sewage lagoons and landfills in rural Alaska are significant probable sources of fecal bacteria migrating to offsite water resources during snowmelt runoff. This study demonstrated that uncontrolled snowmelt and rainwater runoff at waste sites can transmit indicator organisms, and potentially pathogenic organisms as well, into nearby water resources. Moreover, it is likely that in many

instances, the surface waters immediately down gradient of waste sites would not meet state microbial water quality standards for any designated use. Further study is recommended in areas such as sewage lagoons and mixed solid waste/human waste sites where microbial communities may persist for long periods in the presence of discarded pharmaceuticals. In these instances, the microbes could potentially develop resistances to antibiotic/antiviral drugs, thus imposing an even greater risk to community health. As similar results have been demonstrated in marine environments (Neela et al., 2007) and in bacteria living in coastal fresh water sites (Kimiran-Erdem et al., 2007; Kuemmerer, 2004) impacted by sewage runoff, it seems likely that rural Alaska's microbial-impacted sites may represent a similar public and environmental health concern.

6. References

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7. Figures

Figure III-1: Rural Alaska waste facility conditions.

Figure III-2: Constructed lysimeters setting on October 2008.

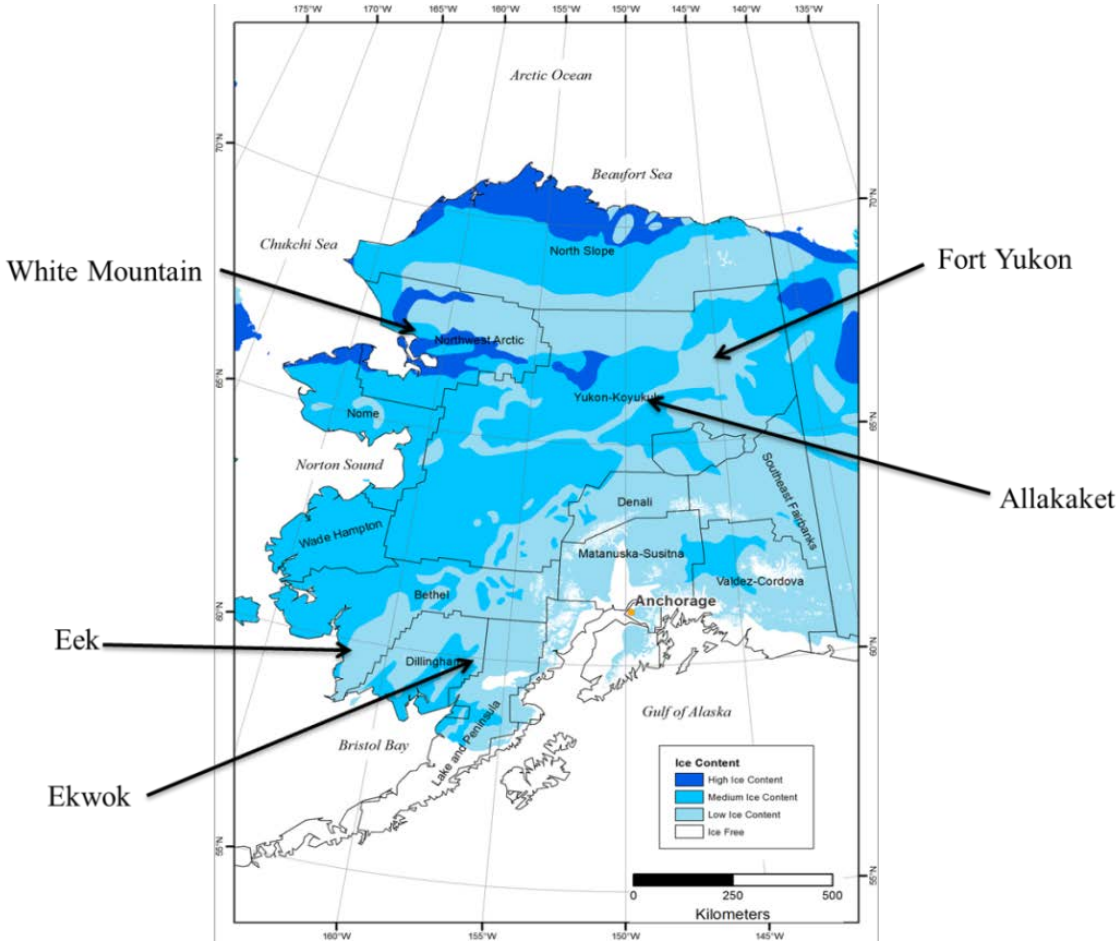

Figure III-3: Illustration of rural Alaska communities region.

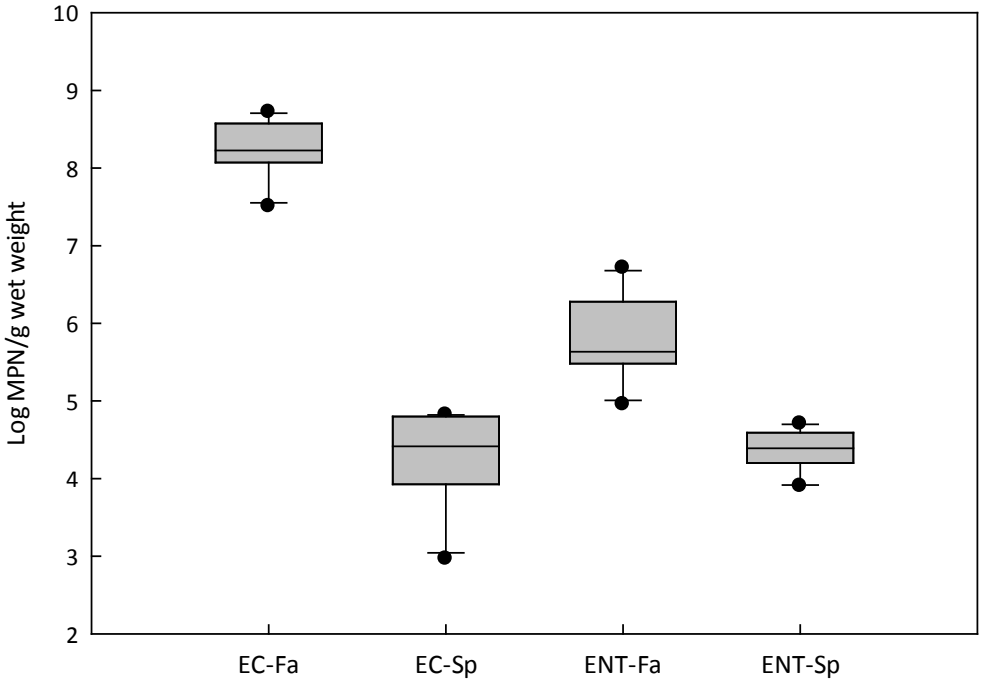

Figure III-4: MIO survivability in manure before and after storage (-40 °C) for six months.

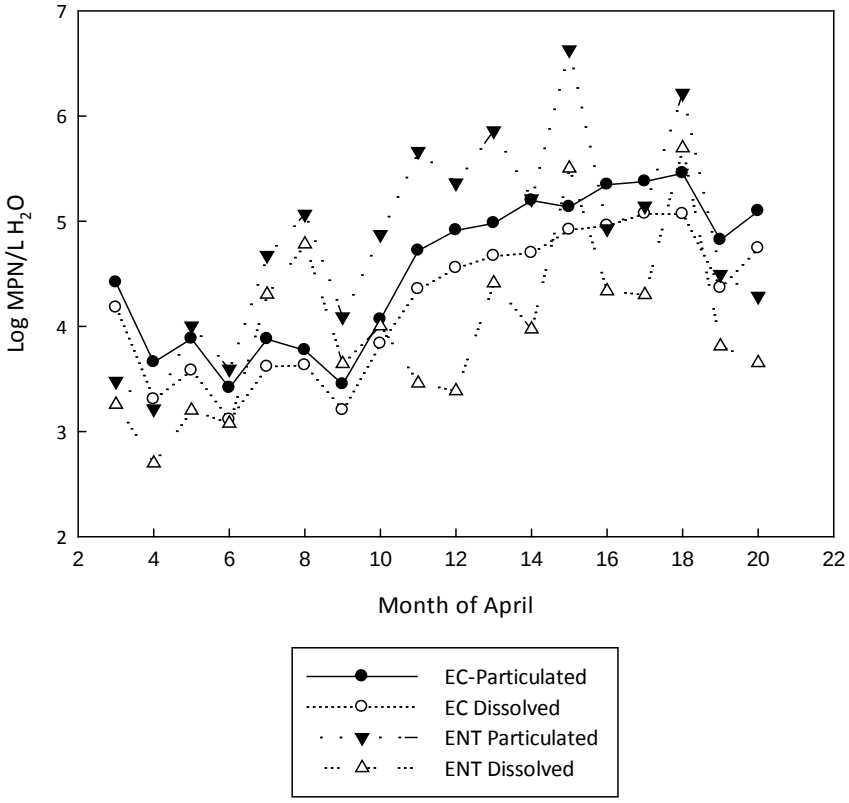

Figure III-5: Lysimeter Total MIO Load per Day collected in meltwater runoff during the month of April 2009.

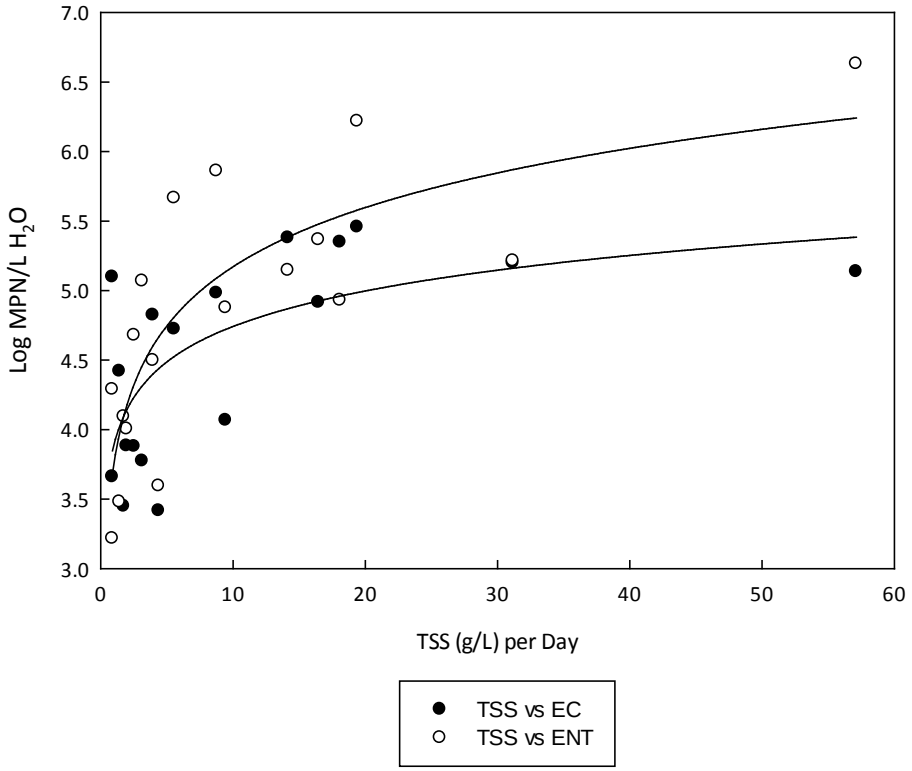

Figure III-6: Lysimeter MIO particulate fraction correlation with total suspended solids associated with snowmelt discharge per day. An exponential correlation was found for ENT MIO and TSS with a $y = 0.614 \ln(x) + 3.76$ and a R^2 value of 0.65, whereas EC MIO and TSS with $y = 0.37 \ln(x) + 3.90$ and a R^2 value of 0.41.

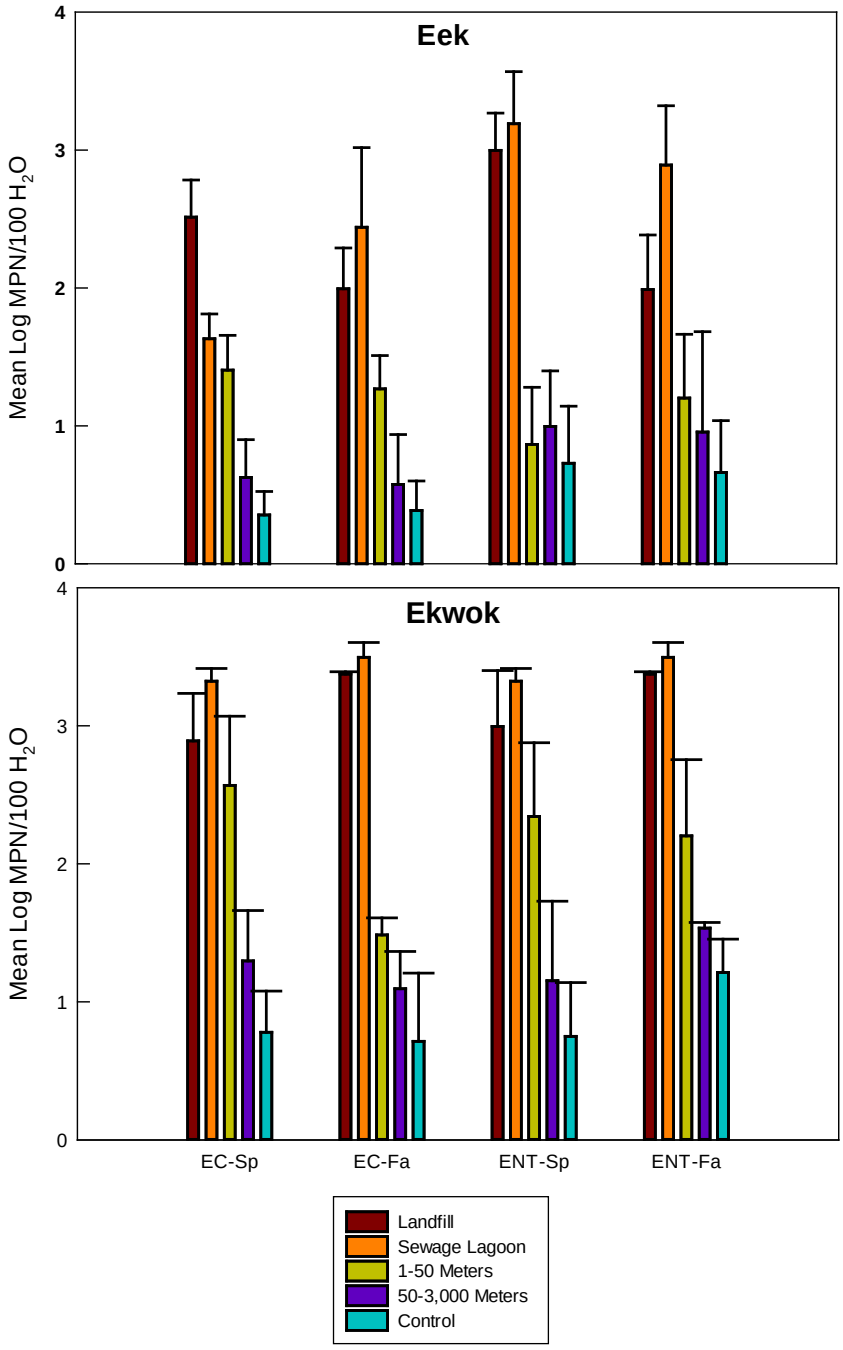

Figure III-7a: Spring and fall observed EC and ENT mean Log MPN in surface water samples.

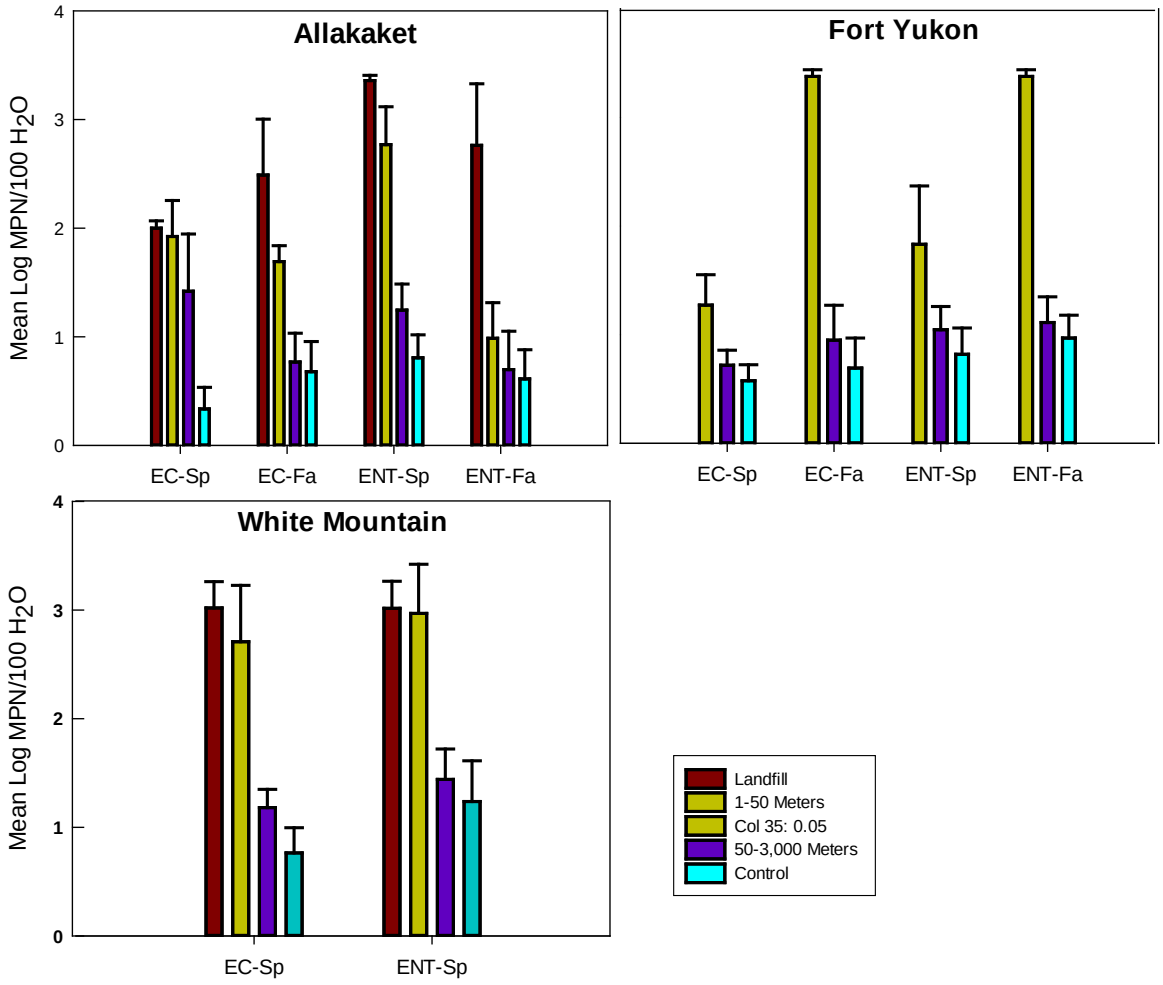

Figure III-7b: Spring and fall observed EC and ENT mean Log MPN in surface water samples.

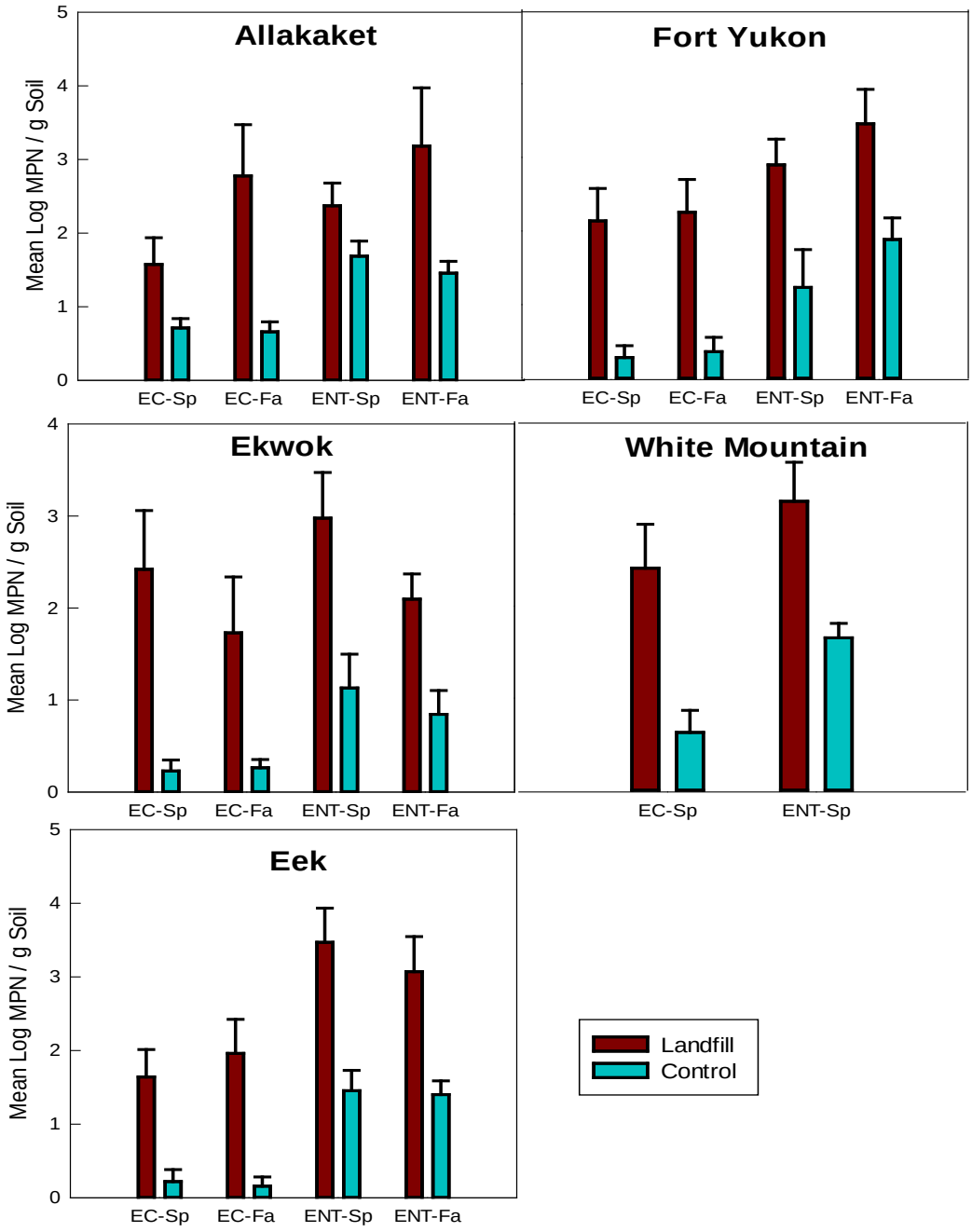

Figure III-8: Spring and fall observed EC and ENT mean Log MPN in soils.

8. Tables

Table III-1: Climatic conditions at each sampling location (Shulske and Wendler 2007)

Location	Region Representative	Temperature Ranges °C	Annual Average Rain Precipitation (mm)	Annual Average Snow Precipitation (cm)
Ekwok	Discontinuous Permafrost on wet tundra ground	-43 to 29	140.0	140.2
Eek	Discontinuous Permafrost on saturated tundra ground	-44 to 30	406.4	134.4
White Mountain	Permafrost impacted on bedrock and wet tundra ground	-48 to 37	432	172.7
Fort Yukon	Discontinuous permafrost on wet tundra ground	-54 to 33	304.8	157.5
Allakaket	Permafrost impacted on wet tundra ground	-57 to 34	604.2	22.4

Table III-2: Samples collected at each sample location

Sample ID	Sample Locations	Ekwok	Eek	White Mountain	Fort Yukon	Allakaket
A	Surface water within the landfill	22*	46	29	0	9
B	Surface water directly offsite the landfill	14	36	12	21	12
C	Surface water 50-3,000 m down-gradient	16	37	12	35	20
D	Surface water controls	28	41	15	42	11
E	Sewage lagoon	10	8	0	7	0
aa	Landfill impacted soils	20	36	20	31	20
ab	Control soils	12	13	10	12	8

*Sample number at each specific sampling site

Table III-3: Range of physical characteristics for all waters

Location	ID	pH (unit)	Temperature (^{0}C)	Conductivity (µS cm$^-$)	TSS (mg L$^-$)
Ekwok	A	6.4 - 7.7	5.2 - 19.5	194.2 - 282.4	670.3 - 4,247.0
	B	5.8 - 7.4	2.2 - 9.3	435 - 507.0	130.5 - 210.6
	C	6.3 - 7.5	1.9 - 11.3	14.6 - 228.6	7.5 - 30.3
	D	7.2 - 7.8	1.1 - 11.1	18.6 - 228.6	4.5 - 5.1
	E	7.4 - 8.4	0.6 - 9.2	810.0 - η	300.0 - η
Eek	A	6.4 -7.6	0.2 - 12.0	185.8 - 567.4	73.3 - 514.3
	B	6.4 - 7.7	0.2 - 13.9	77.0 - 130.4	137.5 - 550.0
	C	5.7 - 7.7	0.4 - 13.9	14.0 - 150.1	6.7 - 8.1
	D	6.3 - 7.7	0.7 - 13.9	17.8 – 136.7	8.1 - 12.1
	E	6.5 - 8.2	1.6 - 12.9	175.8 - 212.5	514.3 - η
White Mountain	A	7.3 - 8.2	4.7 - 21.6	200.2 - 2,200.0	71.1 - 309.3
	B	6.7 - 8.7	3.2 - 20.7	574.0 - 1,920.0	130.3 - 208.5
	C	6.7 - 8.7	3.2 - 11.5	245.3 - 580.0	10.0 - 27.0
	D	7.8 - 8.1	2.3 - 13.4	65.2 - 136.5	8.7 - 10.0
Fort Yukon	B	7.2 - 8.4	5.2 - 15.5	748.9 - 1,980.0	186.0 - 4,962.0
	C	7.8 - 8.6	12.8 - 21.3	22.0 - 214.6	26.7 - 50.0
	D	6.8 - 8.6	13.0 - 18.9	19.0 - 526.7	5.7 -171.4
Allakaket	A	6.1 - 7.9	11.3 - 17.4	178.0 - 2,232.0	110.1 - 170.8
	B	7.8 - 8.4	13.4 - 16.6	449.2 - 922.0	21.0 -125.33
	C	7.1 - 7.7	16.7 - 17.2	150.0 - 310.0	22.7 - η
	D	7.5 - 7.9	14.7 - 16.1	290.0 - 444.0	2.7 - 22.50
Lysimeter		7.0 - 8.7	0.6 - 15.5	63.4 - 968.0	31.8- 482.0

*A - Surface water samples within the landfill; B - Surface water samples directly offsite the landfill; C - Surface water 50-3,000 m down-gradient of the landfill; D - Surface water controls; E - Sewage Lagoon and η - only measured one time.

Table III-4: Average physiochemical parameters of all soils

Location	ID	pH (unit)	Moisture Content (wet %)	Sand (%)	Silt (%)	Clay (%)
Ekwok	aa	6.9	35.1	3.1	28.6	68.3
	ab	6.8	36.2	2.5	30.9	66.7
Eek	aa	6.0	47.4	2.3	19.4	78.3
	ab	5.1	28.1	0.1	13.6	86.3
White Mountain	aa	7.7	31.9	4.9	44.4	50.6
	ab	7.8	22.9	0.3	41.2	58.4
Fort Yukon	aa	8.7	41.7	2.9	27.0	70.1
	ab	7.0	30.7	2.1	19.6	78.3
Allakaket	aa	8.6	33.8	6.0	26.4	67.6
	ab	7.0	23.5	3.3	34.0	62.7
Lysimeter		7.4	11.2	44.4	55.6	0.0

* aa - Landfill impacted soil samples and ab - Control soil samples

Table III-5: Average Log MPN/100 mL H_2O for MIO in surface water and soil samples with reported confidence interval (CI) of the population mean

Location	ID**	n	Mean Log* MPN/100m L H_2O E.coli	CI ✦ E.coli	ID**	n	Mean Log* MPN/100m L H_2O ENT	CI ✦ ENT
Ekwok	A	23	> 3.0	± 0.3	$A_{1,2}$	23	> 3.1	± 0.3
	B	15	> 2.2	± 0.4	B_1	15	> 2.8	± 0.3
	C	17	1.1	± 0.3	C	17	1.2	± 0.4
	D	29	0.7	± 0.2	D	29	0.7	± 0.3
	E	11	> 3.5	± 0.1	E_2	11	> 3.5	± 0.1
	aa	31	1.5	± 0.6	aa	31	2.4	± 0.4
	ab	13	0.2	± 0.1	ab	13	1.0	± 0.3
Eek	A_1	47	> 2.3	± 0.2	A	47	> 2.5	± 0.3
	B	37	1.3	± 0.2	B_1	37	1.1	± 0.3
	C_2	38	0.8	± 0.2	$C_{1,2}$	38	1.2	± 0.4
	D_2	43	0.3	± 0.1	D_2	43	0.5	± 0.2
	E_1	13	> 2.1	± 0.5	E	13	> 3.1	± 0.3
	aa	37	1.4	± 0.4	aa	37	3.0	± 0.3
	ab	14	0.2	± 0.1	ab	14	1.5	± 0.3
White Mountain	A_1	30	3.0	± 0.2	A_1	30	3.0	± 0.2
	B_1	13	2.7	± 0.5	B_1	13	3.0	± 0.4
	C	13	1.2	± 0.2	C_2	13	1.4	± 0.3
	D	16	0.8	± 0.2	D_2	16	1.2	± 0.4
	aa	21	2.4	± 0.5	aa	21	3.1	± 0.4
	ab	11	0.6	± 0.2	ab	11	1.7	± 0.2
Fort Yukon	B	22	1.6	± 0.4	B	22	> 2.1	± 0.5
	C_1	36	0.7	± 0.1	C_1	36	1.0	± 0.2
	D_1	43	0.6	± 0.1	D_1	43	0.9	± 0.2
	aa	32	1.7	± 0.4	aa	32	3.1	± 0.3
	ab	13	0.1	± 0.1	ab	13	1.4	± 0.5
Allakaket	A_1	9	2.6	± 0.5	A_1	9	> 2.8	± 0.6
	B_1	12	1.8	± 0.3	B_1	12	> 2.1	± 0.7
	C_1	21	1.4	± 0.4	C	21	1.2	± 0.3
	D	12	0.5	± 0.2	D	12	0.6	± 0.3
	aa	20	1.9	± 0.4	aa	20	2.6	± 0.4
	ab	8	0.6	± 0.1	ab	8	0.8	± 0.2
Lysimeter			4.5	± 0.7			4.8	± 0.9

*MPN number refers to the number of *E. coli* or *ENT* colony forming units found in 100mL of water enumerated via the most probable number method. Mean Log MPN values preceded by a "greater than" sign indicate that at least one sample in the set yielded results exceeding the detection capacity of the MPN test (Log MPN 3.4/100 mL H_2O). In these instances, the sample values were assumed to equal the upper detection limit of the test.

**Numerical subscripts following site ID indicate the results of means testing via one-tailed Student t test. Sample IDs within each analyte/location group having common numerical subscripts were not shown to have significantly different means at the p=0.05 level. Sample IDs with no subscript indicate that their mean values were significantly different from all others in their analyte/location group.

*** where A - Surface water samples within the landfill, B - Surface water samples directly offsite the landfill, C - Surface water 50-3,000 m down-gradient of the landfill, D - Surface water controls, E - Sewage Lagoon, aa - Landfill impacted soils and ab - Control soils.

✦ Confidence interval (CI) for the population mean via using population standard deviation with 95% confidence level.

Table III-6: Pearson Correlation of physiochemical characteristics and MIO density load in waters

	MPN ENT	**pH**	**Temperature**	**Conductivity**	**TSS**
MPN EC	0.844 3.5E-055 199	0.0548 0.442 199	0.007 0.917 199	0.004 0.956 199	0.505 2.9E-014 199
MPN ENT		0.0564 0.429 199	0.0830 0.244 199	0.004 0.961 199	0.508 1.9E-014 199
pH			0.282 5.1E-06 199	0.356 2.5E-08 199	0.085 0.232 199
Temperature				0.260 2.1E-05 199	0.214 0.003 199
Conductivity					0.370 7.5E-09 199

*For pairs with P values greater than 0.050, there is no significant relationship between the two variables.

Cell Contents:
Correlation Coefficient
P Value
Number of Samples

Table III-7: Pearson Correlation of physiochemical characteristics and MIO density load in soils

	MPN ENT	pH	Moisture Content	Sand	Silt	Clay
MPN EC	0.492 5.50E-07 165	0.234 0.024 165	0.214 0.038 165	0.111 0.291 165	0.099 0.344 165	0.007 0.945 165
MPN ENT		0.172 0.099 165	0.501 3.20E-07 165	0.168 0.108 165	0.129 0.217 165	0.294 0.004 165
pH			0.123 0.239 165	0.802 4.90E-22 165	0.779 3.90E-20 165	0.571 2.20E-09 165
Moisture Content				-0.750 0.475 165	-0.109 0.296 165	0.444 8.40E-06 165
Sand					0.991 2.40E-81 165	0.68 6.80E-14 165
Silt						0.617 4.50E-11 165

*For pairs with P values greater than 0.050, there is no significant relationship between the two variables.

Cell Contents:
Correlation Coefficient
P Value
Number of Samples

Chapter IV

Detection of Organic Pollutants in Rural Alaskan Landfill & Wastewater Systems

Abstract

In rural Alaska, small communities' landfill and sewage lagoon were tested for potential of release of organic pollutants to surrounding freshwater systems. Since wastewater and/or landfill leachates in rural Alaska receive minimal treatment, poorly-maintained sewage lagoons and solid waste facilities are potential sources of xenobiotic organic compounds to the surrounding environment. This study intended to identify and characterize trace levels of benzotriazoles (BT), pharmaceutical and phthalates in landfill leachate and raw sewage samples by liquid chromatograph tandem mass spectrometry. The results of this study identified the presence of pharmaceuticals (sulfamethoxazole, trimethoprim, ibuprofen and acetaminophen, bupropion, caffeine or 1,7-dimethylxanthine), benzotriazoles (1 H-benzotriazole (BT) or 4&5-methylbenzotriazole (tolyltriazole TT), and phthalates (DEP, DEHP, DNOP, DBP, DMP or BBP). The concentration levels detected were similar or elevated in and around traditional landfills and sewage lagoons compared to modern constructed landfills and wastewater treatment effluents. The results highlight the relevance of further and more comprehensive studies to assess xenobiotic (XOC) emissions caused by direct discharge or leaking of rural waste facilities and by climatic factors such as snowmelt and rainstorms, which can lead to migration of XOCs into adjacent water bodies and potentially impact water quality.

[1] Mutter E.M., Hagedorn B., Barnes D., and William Schnabel W. Fairbanks 2014. Detection of Organic Pollutants in Rural Alaskan Landfill & Wastewater Systems. Prepared for submission in Journal of Water and Health.

1. Introduction

In rural Alaska, communities are especially sensitive to changes in their surrounding ecosystem due to the subsistence activities of community members. Ineffective solid waste and wastewater disposal pose a potential threat to the environment and subsistence lifestyle as a result of high concentrations of uncontrolled hazardous and toxic waste that can contaminate drinking water and traditional food resources. Currently, rural Alaska waste facilities are poorly constructed, operated and maintained (ANTHC, 2007; Duigou, 2006). Activities associated with the design, construction, operation and management of rural arctic and subarctic waste facilities are challenged by many communities' geographic isolation, socioeconomic factors and extreme climatic and geomorphological conditions (i.e. underlying bedrock or permafrost and poorly drained soils). Most rural Alaskan communities are sparsely populated, have only small local economies and tax bases, and struggle with high energy costs, transportation costs, short construction seasons, and lack of sufficient local knowledge to maintain and operate a functional wastewater and/or solid waste facility (Gunnarsdottir et al., 2013; Patterson et al., 2012). These geographic, socioeconomic, extreme climatic and environmental conditions, contribute to traditional town dump sites, which are constructed and operated without proper site assessment or monitoring (EPA, 1998).

In rural Alaska, communities with 55% or fewer homes served by piped septic or other means of transporting human waste from the home besides hand carrying the waste in buckets (known as honeybuckets) are considered to be unserved communities (ADEC, 2013). Of the approximately 240 rural Alaskan communities, 42 are unserved (ADEC, 2013). For homes that do not have sanitary means of disposing of human waste (e.g. piped septic) the waste is manually hauled in honeybuckets and discharged together with solid waste in dump sites (Zender et al., 2003). Some communities rely on individual septic systems, while relatively larger communities will have some form of a sewage system with a constructed sewage lagoon. In small rural communities (<1,000 residents) untreated, uncontrolled, and unmonitored wastewater is allowed to discharge directly into surface waters, or allowed to infiltrate directly into ground (ADEC, 2009; Duigou, 2006; Troy, 2007).

The pharmaceuticals, phthalates and benzotrialzole compounds were selected for this study because they were identified and reported as xenobiotic organic compounds (XOCs) related to household waste and wastewater (Jjemba, 2006; Kuemmerer, 2008; Kuemmerer, 2009). The

composition of waste generated in rural Alaska communities has changed over recent decades from traditional organic materials associated with a subsistence lifestyle to more recalcitrant or hazardous waste products such as antifreeze, gasoline, batteries, paints, synthetic packaging material, electronics, construction and demolition debris, personal hygiene products, and pharmaceutical products (Gunnarsdottir et al., 2013; Matsuura et al., 2008; Vrijheid, 2000). Considering the increase of rural communities' waste generation rate and the change in waste composition, traditional open dumps in rural Alaska present a more severe threat to surrounding water resources and environments than originally thought. The possible exposure of these environments to chemical pollutants is of particular concern given their low assimilative capacity. Studies have shown that freshwater systems in arctic and subarctic regions are particularly vulnerable to direct release of untreated wastewater and waste leachate, due to the low biological diversity, low amount of nutrients and extreme seasonal variation in light (Bach et al., 2009; Bergheim et al., 2010; Kallenborn et al., 2008; Schubert and Heintzman, 1994). Furthermore a changing climate with increasing temperature and precipitation in arctic and subarctic regions is impacting rural waste facilities, sewage-piping systems and natural wetland utilized as leach fields, as a result of more frequent flooding and erosion as well as permafrost degradation (AMPA, 2003; GAO, 2003; Jeffries et al., 2013). The purpose of this study was to determine the occurrence of select pharmaceuticals, phthalates, and benzotriazoles in sewage lagoons and open dumps and surrounding surface waters in rural Alaska. This is the first study that has documented the presence of these compounds in rural Alaskan waste impacted surface waters.

2. Background

Environmental concerns related to pharmaceuticals, phthalates, and benzotrialzoles are associated with their chemical, physical, and biological properties related to fate and transport (e.g., partitioning coefficients and pH) (Jjemba, 2006; Kümmerer, 2009). Therefore, to understand XOCs proliferation in the environment, the entire biogeochemical cycle from initial use up to their effects on humans or on other target organisms or their environmental fate have to be considered. For example metabolized or unmetabolized pharmaceuticals excreted by humans can be either active or inactive in the environment, depending on polarity of the compound and environmental physiochemical conditions such as pH and organic matter content (Kuemmerer, 2009). As described by Richardson and Ternes (2005), there are several pathways that

pharmaceuticals can follow once they are in the environment. For instance biodegradation and biotransformation via metabolism or other mechanisms can result in pharmaceutical break-down into other compounds, which can possibly be more harmful than the parent compound and bioavailable to non-target organisms. A good example of this process is acetaminophen, which can be transformed into two toxicants, 1,4-benzoquinone and n-acetyl-p-benoquinone imine, (Botitis et al., 2007; Castro et al., 2001). Phthalates found in products such as perfumes and cosmetics (DMP, DEP), cellulose (DEP), as well as inks, polymer dispersions and coatings (DBP, BBP) (Furtmann, 1993; OSPARCOM., 1997), have been found in waste impacted water bodies in moderate climate regions with concentrations that are sufficient enough to disrupt endocrine functions in human and wildlife (Koch and Calafat, 2009; Kuemmerer, 2009; Meeker et al., 2009; Oeman et al., 1997; Teuten et al., 2009; vom Saal and Welshons, 2006).

Studies performed to assess wastewater and landfill leachate in moderate climates demonstrated the presence of XOCs in effluents and described their implications to the aquatic environment and human health (Imhof and Muehlemann, 2005; Jjemba, 2006; Koch and Calafat, 2009; Kuemmerer, 2008; Lincoln et al., 2007; Minh et al., 2006; Slack et al., 2005; Vrijheid, 2000; Yu, 2005). Pharmaceuticals from unused or outdated products such as acetaminophen, ibuprofen, lincomycin, metformin (Kallenborn et al., 2008; Musson and Townsend, 2009; Trischler et al., 2012; Vrijheid, 2000), personal hygiene and household cleaning products (Christensen et al., 2001; Coors et al., 2003; Kawagoshi et al., 2003; Mersiowsky, 2002; Mor et al., 2006), and plasticizers (Kjeldsen et al., 2002; Mersiowsky, 2002; Slack et al., 2005) have been detected in landfill leachate and impacted surface and ground waters. A landfill leachate study conducted in Germany found that ibuprofen, propenazone, and phanzone were the most abundant drugs among the analgesics and anti-inflammatory drugs. Anxiolytic sedatives and antipsychotic drugs, particular primidone, carbamazepine, and diazepam were detected in concentrations that were often higher than typical average concentration levels found in German wastewater and surface water (Kuemmerer, 2008).

Pharmaceuticals such as anti-inflammatory (ibuprofen), antibiotics (chlortetracycline, thiabandazole), stimulants (coffee, nicotine), reproductive hormones (17-β-estradiol and 17 α-ethinyl-estradiol) and antidepressant drugs have been detected in raw sewage, treatment plant effluents, surface and groundwater, manure, and soil in Europe since the 1980's (Kuemmerer, 2008; Kuemmerer, 2009). Synthetic organic compounds, such as personal hygiene and

pharmaceuticals, surfactants, and flame retardants discharged from wastewater treatment effluent have also been detected in ground and surface waters in the United States (Barnes et al., 2008; Cahill et al., 2004; Focazio et al., 2008; Glassmeyer et al., 2005; Lajeunesse et al., 2008). The United States Geological Survey (USGS) collected and tested samples from streams, raw untreated drinking water sources and groundwater sites, which are known or suspected to be influenced by human and agricultural waste across the United States for about 100 organic wastewater contaminants (Barnes et al., 2008; Focazio et al., 2008; Glassmeyer et al., 2005; Kolpin et al., 2002). The stream studies detected surfactant metabolites, pharmaceuticals and personal care products in 61% of tested streams and rivers, with a concentration range of 0.2 to 40 ppb (Ferguson et al., 2001; Klecka et al., 2007; Kolpin et al., 2002). A study conducted in Sisimiut, Greenland found pharmaceuticals in domestic and hospital wastewater (Bach et al., 2010).

Benzotriazole and its methylated form (4- and 5 -ethyl Benzotriazole) are used as a corrosion inhibitor in a number of automotive and household substances such as coolant, antifreeze in windshield wiper and dishwasher soap. In addition it can be found as a UV stabilizer in a number of rubber and plastic parts. It has been found to be one of the 10 most abundant contaminants in surface waters in Europe (Loos et al., 2009), and determined to be highly toxic to aquatic organisms (Giger et al., 2006a; Pillard et al., 2001).While not regulated in the US, the reporting level in Europe is 0.1 $\mu g\ L^{-1}$ in aquatic environments. The high solubility of Benzotriazoles in water promotes rapid mobilization during snowmelt into waterways where they can be distributed to water bodies and soils.

A list of the analyzed XOCs and their predominant occurrence is given in Table 1.

There is very little known about these organic pollutants regarding transport processes, toxicological impacts posed to human and environmental health, and their ability to persist in cold environments such as Alaska (Ahel et al., 1994; Giger et al., 2006b; Ternes et al., 2004). Most studies on the impact of XOCs on freshwater systems have been conducted on wastewater treatment effluents and landfill leachates in highly populated areas with moderate climates. In rural Alaska, where treatment and disposal of wastewater is less controlled than other regions of the United States, it is likely that XOC’s are migrating into surrounding water resources, which are often primary drinking water sources. It is hypothesized that concentrations of XOC’s in these

untreated and uncontrolled wastewater discharges and leachates will be higher than the concentrations observed in modern treatment plant effluents. In addition climatic factors such as snowmelt and rainstorms will lead to migration of these constituents into adjacent water resources. This study provides the first indication of XOCs in dump leachate, sewage lagoons and freshwater bodies in rural Alaska, and is intended to create a baseline for future investigations. The focus of this study was to identify and quantify concentration levels for selected pharmaceuticals, phthalates and benzotriazoles in rural open dumps, sewage lagoons, proximal surface water, and downstream surface waters. The selected organic pollutants were chosen based upon observed concentration levels and frequency of occurrence in streams, raw untreated drinking water sources and groundwater sites reported by the United States Geological Survey (USGS) (Barnes et al., 2008; Focazio et al., 2008; Glassmeyer et al., 2005; Kolpin et al., 2002; Loos et al., 2009).

3. Methodology

3.1 Study Sites

Five rural Alaskan communities were chosen for this study: Ekwok, Eek, White Mountain, Fort Yukon, and Allakaket. The communities were intended to represent a cross section of remote communities in rural Alaska. Furthermore, the communities' open dumps and sewage lagoons are situated in four different arctic and subarctic environments (e.g. open tundra, ponded sites, permafrost and permafrost impacted). At the time of this study, each community had an open dump, and one village (Fort Yukon) also had a closed dump. A honeybucket lagoon was located in Eek and a constructed sewage lagoon in Ekwok. The open dumps and sewage lagoons in each of these communities were sampled to evaluate the presence of pharmaceuticals, phthalates and benzotriazoles. Each waste facility is in close proximity to the community and impacted by seasonal snowmelt and rain water runoff. Rural Alaska communities and their representative regions are illustrated in Figure 1. Following is a description of the waste facility sampled in each community.

Ekwok is a served community of approximately 130 residents and located along the Nushagak River, 69 km northeast of Dillingham and 302 km southwest of Anchorage (Census, Bureau, 2010). The sampling site is an approximately 30 year old below ground dump constructed on

excavated tundra located approximately 2.4 km northeast of the village. The open dump is 2.3 km^2 in area and 3 to 4.5 m deep, creating a 22% slope towards lowland area. The soil-lined constructed sewage lagoon is heavily overgrown with vegetation and located 500 m from the community, and approximately 800 m from the Nushagak River.

The community of Eek is located on the south bank of the Eek River and has approximately 208 residents. Eek is located 19 km east of the mouth of Kuskokwim River and approximately 56 km south of Bethel in the Yukon-Kuskokwim Delta (Census, Bureau, 2010). The samples were obtained at an approximately 30 year old ponded landfill and an adjacently located honeybucket lagoon, both with the dimension of 0.8 km^2. Both waste sites are located less than 1.6 km away from the community. Based on a survey of the waste sites, the hydrologic system is complex and influenced by tides, permafrost, and surface water. Saturated tundra ground with standing water is encountered around the waste sites all year round, but the site itself is not subject to flooding (Patterson et al., 2012).

White Mountain a community of 224 residents, and is located 100 km east of Nome on the Seward Peninsula on the west bank of Fish River (Census, Bureau, 2010). The approximately 30 year old above ground dump is located in an upland area approximately 400 m east of the village and north of the river. The open dump is 0.6 km^2 in area and rises up approximately 4.5 m to create 18% slope east/southeast towards a lowland area. Standing water occurs during snowmelt and rain events. The natural drainage area is observed to the east/southeast side of the open dump site.

The largest community in the study, Fort Yukon, is a community of approximately 600 residents (Census, Bureau, 2010). Fort Yukon is located at the confluence of the Yukon River and Porcupine River approximately 233 km northeast of Fairbanks. An approximately 30 year old above-ground dump is located in an upland area 2.4 km from the community. The 0.2 km^2 open dump is situated along the edge of an old river bank 8 to 15 m higher than the lowland area, creating an approximate 32% slope towards the river. The dump was closed and covered with gravel prior to the start of the study. The lagoon sampled in this study is a lined system located approximated 3 km from the community.

Allakaket is a community of 190 residents located approximately 306 km northwest of Fairbanks, on the south bank of the Koyukuk River (Census, Bureau, 2010). The approximately 10 year old above ground dump is located on an upland area along a ridge approximately 1.6km south from the old village area, and approximately 1.2 km from the new village area. The open dump has an area of 0.7 km^2. A natural drainage area is formed with a slope of approximately 4% incline to the south; characterized by shallow permafrost and tundra ground.

3.2 Onsite Surface Water and Wastewater Sample Collection

On two consecutive days in spring 2010, fall 2010, spring 2011 and fall 2011 surface water samples were collected from the five rural open dumps, from the proximal waters located within a 50 m radius of the landfills, and from the sewage lagoons. All water samples were collected in 250 mL glass bottles (previously cleaned and baked at 400^oC) and preserved with HCL to pH 2 after arrival in the laboratory. For this study, the sampling procedure was consistent throughout each sampling event and sample location to ensure consistency. Landfill impacted surface waters were collected after considering individual hydrologic pathways at the landfills, and 1-20 m down-gradient. Raw sewage water samples were obtained approximately 1m from the edge of honeybucket and a constructed sewage lagoon. Control surface water samples were collected from undisturbed sites least 1 km away from waste site at each location. The sample numbers obtained from each location and sample site are listed in Table 2.

3.3 Analytical Methods

For this baseline study a total of twenty-three organic pollutants: 14 pharmaceuticals, 3 benzotriazoles and 7 phthalates were selected to identify and quantify concentration levels in five rural landfill impacted surface water and raw sewage samples. The organic pollutants and analytical details are listed in Table 3.

All analytical work was performed in-house at the Applied Science Engineering Technology laboratory, University of Alaska Anchorage. Upon arrival at the laboratory the samples were acidified with HCL to pH 2 within 12 hrs. and spiked with 100 ng of Caffeine-d_3, 200 ng DEHP-d_4, 200 ng DBP-d_4, 200ng BPA-d_{16}, and 200 ng 5,6 dimethylbenzotriazole (Sigma Aldrich)

surrogates. Waste leachate surface water and raw sewage samples contained a large amount of suspended materials. To remove all organic and suspended particulates and exclude microbial organisms, the samples were filtered first through 0.7 μm and then through 0.45 μm Whatman GF/C membrane filters. The samples were then stored at 4^{o}C until further preparation.

Solid phase extraction (SPE) and purification of surface water and raw samples for pharmaceuticals and benzotriazoles were performed using an Oasis hydrophobic lipophilic balanced (HLB) (6cc/500 mg) cartridge (Waters Ltd., Watford, UK) following methods described in Hagedorn et al. (2013). The hydrophobic lipophilic balanced sorbent was chosen due to the ability to retain the analysts of interest upon a variety of physicochemical properties (e.g. pKa and polarity). SPE cartridges were pre-conditioned with 3x2 mL of methanol followed by 3x2 mL of dH_2O (LC MS grade) prior to separation. Up to 250 mL of water sample were passed through the cartridge using a high volume vacuum SPE manifold at a rate of 1 to 2 mL/min for extraction. Difficulties were experienced with the complex matrix containing high organic content plugging SPE cartridge. Water samples volume was adjusted accordingly between 100 mL to 250 mL to avoid overloading the SPE cartridge. SPE cartridge was rinsed after sample passed through with 2 mL H_2O:Methanol (95/5 v.v.) and vacuum dried for 5 min to remove excess water. Pharmaceuticals and benzotriazoles were eluted with 5 mL Methanol:Dichloromethane (90/10 v.v.) and evaporated under steady nitrogen flow using (Nitro Vap) to near dryness at 30^{o}C. Residue were spiked with 200 ng caffeine-d_3, 500 ng ibuprofen-d3, 200 ng carbamazepine $C_{13}N_{15}$, 500 ng cotinine-d_3, 500 ng nicotine-d_3, and 200 ng 1H-benzotriazole-d4 (obtained from Sigma Aldrich) as internal standards and reconstituted to 1 mL with using Methanol:H_2O (50/50 v.v.) mixture. Samples were vortexted for 30 seconds for complete mixing and transferred to a 1 mL auto sample vial by filtering through 0.2 μm polytetrafluoroethylene/Teflon syringe filter and store at 2°C until HLC/MSMS analysis. Blanks and spiked samples were added to each batch for quality control.

For the phthalate analysis a stringent cleaning procedure was applied due to the prevalence of phthalate constituents in the laboratory environment. The laboratory equipment cleaning procedure for glassware to remove any organic residues, as well as analytical grade anhydrous primary-secondary amine sorbent (PSA), $MgSO_4$ and $NaSO_4$ followed the method described in Ali et al, (in review). For phthalate analysis a liquid-liquid extraction was performed using hexane. Approximately 150 mL of water sample was filled into a 200 mL separation funnel with

10 mL of hexane ND. The samples were shaken for 1hr using a long-arm rotator shaker and then rested for 2 hrs. to allow full separation of hexane from the water phase. The layer of hexane was removed and transferred into a pre-cleaned 60 mL glass vial; the process was repeated 3 times for best recovery. The extraction and purification for phthalates followed Ali et al., (in review) using a dispersive solid phase extraction with 200 mg $MgSO_4$ and 50 mg PSA added to the extract and vortexed for 2 min followed by 2 min centrifugation. The extract was transferred to a TurboVap tube (Parker Blaston) by passing the solvent through freshly cleaned $NaSO_4$ contained in a sintered glass filter and rinsed with 2x20 mL of LC grade acetone J.T. Baker (PA, USA), to remove any residual water. The eluent was evaporated under steady nitrogen flow using a NitroVap (Parker Balston) at 30^{o}C to near dryness. Residues were spiked with 100 ng DEP-d4 and reconstituted to 1 mL with methanol/H_2O (50/50 v.v.). Samples were then filtered through 0.2 µm polytetrafluoroethylene/Teflon syringe filter into a 1 mL auto sample and store at 2°C until HPLC/MSMS analysis.

Instrumentation methods for pharmaceutical, benzotriazoles, and phthalates are described by Ede (2012), Hagedorn et al. (2013), and Ali et al., (in review), respectively. A Liquid Chromatograph (Agilent 1200) Tandem Mass spectrometer (Agilent® 6140B) with electron spray ionization (ESI) source was used for pharmaceutical and benzotrialzole identification. An Agilent Zorbax SB-C-18 Rapid Resolution Cartridge (2.1 x 30 mm, 3.5 mm) connected to a Zorbax Extend C18 guard column was used for compound separation. Column separation of compounds was achieved with gradients of A: Methanol and B: Water both spiked with 10 mM formic acid. The gradient was set by a gradient of A: 0-10 min 90%, 10-18min 15%, 18-19.0 min 10%, 19-23 min 10% and 25 min 90%. Post-run was set for A: 5 min- 90% to equilibrate the column before next injection. 2 µL of sample were injected for analysis. The instrumentation optimization was set to +3.5 kV for capillary voltage, gas temperature 325^{o}C, gas flow 12 L min^{-1}, nebulizer pressure 35 psi, vaporizer temperature 330 ^{0}C.

Phthalates were measured with an atmospheric pressure photoionization (APPI) source. Compound separation was performed with an Agilent® ZORBAX Eclipse XDB-C18 analytical column of 30 mm length, 2.1 mm internal diameter and a 3.5 µm particle size and run with a gradient of A: methanol and B: water with 5 mM ammonium format set to A: 0-6 min. 85 to 90%; 6-8 min. 90 to 95%; 8-9 min. 95 to 100%; 9-19 min. 100%; 19-20 min. 100 to 85%. Post-run selected with 5 min to equilibrate the column before next injection of 1µl. The optimized settings

for HPLC MSMS are: capillary voltage 2000V, gas temperature 325 ^{0}C, gas flow 7 L min^{-1}, nebulizer pressure 40 psi, vaporizer temperature 350^{o}C. HPLC-MSMS instrumentation methods for organic compounds are presented in Table 3.

4. Results and Discussion

The individual organic pollutants were observed to occur at highly varying concentrations between rural dumps and sewage lagoons, potentially owing to factors such as heterogeneous waste distribution of different compounds, random sample collection within the dumps and sewage lagoons, the environmental settings of the waste facilities (e.g., hydrologic or permafrost impacts), dilution from rain and snowmelt water, and biodegradation and transformation of the organic compounds. A summary of the pharmaceuticals, phthalates, and benzontrialzoles concentrations measured in this study are presented in Table 4 and Figure 2 and 3.

4.1 Pharmaceuticals

The analyzed wastewater had very high levels of organic material and suspended solids, along with a high abundance of humic acids typical for arctic and subarctic surface waters. The complex matrix resulted in overloading of the SPE cartridge, and also posed challenges for HPLC-MSMS method development due to matrix interference and ionization suppression. The difficulties of removing interfering substances during SPE and HPLC-MSMS ionization suppression lead to reduced extraction recovery and instrumentation limit of detection for lincomycin, enrofloxacin, carbamazepine, sertraline, cotinine and erythromecin-H_2O. For further studies it is recommended that the analysis account for the amphoteric nature of pharmaceutical compounds in order to optimize SPE method recovery percentage. For example pharmaceuticals change their ionic form depending on the pH of the surrounding environment. Ionized states of compounds are always more polar than the uncharged form such as amines and carboxylic acids, therefore the presence of acids such as humic acids in the water can enhance solubility and stability of hydrophobic organic pollutants (Chiou et al., 1986). The wide range of pKa values associated with the pharmaceuticals studied here are listed in Table 4. Furthermore, to overcome HPLC-MSMS matrix interferences and ionization suppression it is advised to follow the

recommendation of Chu and Metcalfe (2007) to perform the method of standard additions. Only pharmaceutical compounds that had >65% recovery (SPE and instrumentation) are considered in this study. The control surface water samples showed no presence above detection limits of any of the tested pharmaceuticals. The detected analytes (and mean concentrations) in waste impacted surface water and raw sewage were sulfamethoxazole (4.95 μg L^{-}), trimethoprim (1.08 μg L^{-}), ibuprofen (16.96 μg L^{-}), acetaminophen (26.87 μg L^{-}), bupropion (0.74 μg L^{-}), caffeine (112.40 μg L^{-}) and the caffeine metabolite 1,7-dimethylxanthine (53.71 μg L^{-}). These pharmaceutical compounds were also identified in other studies conducted on impacted surface waters obtained from engineered constructed landfill leachate and modern treatment plant effluents (Barnes et al., 2008; Brun et al., 2006; Cahill et al., 2004; Focazio et al., 2008; Glassmeyer et al., 2005; Gömez et al., 2007; Klecka et al., 2007; Kolpin et al., 2002; Lopez-Serna et al., 2011; Renew and Huang, 2004) with concentration ranges for sulfamethoxazole (0.02 - 0.57 μg L^{-}), trimethoprim (0.02 - 0.70 μg L^{-}), acetaminophen (0.01 - 0.87 μg L^{-}), caffeine (0.01-6.00 μg L^{-}), 1,7-dimethylxanthine (0.019 μg L^{-}) and ibuprofen (0.02 - 840.00 μg L^{-}). The prevalence of caffeine and ibuprofen and/or its metabolites in the environment is highlighted by their occurrence in seawater samples from Tromso Norway, despite strong tidal current and dilution with the presumably non-polluted North Atlantic water (Weigel et al., 2004). Anti-inflammatory drugs, antidepressants and antibiotics were detected in Greenland wastewater treatment effluent (Kallenborn et al., 2008; Vasskog et al., 2009).

The high concentration levels and abundance of ibuprofen, acetaminophen, caffeine, and 1,7-dimethylxanthine in rural waste impacted surface waters highlight their usage in these rural communities and reflect the worldwide consumption pattern and abundance of these drugs (Fent et al., 2006; WHO, 2010). The high water solubility of these compounds (Bendz et al., 2005; Breton and Boxall, 2003; Kuemmerer et al., 2000) likely promotes their abundance in aquatic ecosystems (Han et al., 2010) and is most likely the reason why these compounds were found in high concentration levels in leachate and surface water samples directly adjacent to the waste facilities.

In particular, ibuprofen concentration levels are of concern due to the ability of ibuprofen to alter the reproduction of vertebrates and invertebrates (Flippin et al., 2007; Han et al., 2010; Hayashi et al., 2008). Studies have also shown that in areas with high microbial densities (i.e. sewage

lagoons and solid waste mixed with human/honey bucket waste), microbial communities can develop resistance to antibiotic/antiviral/antifungal drugs in the presence of pharmaceuticals such as sulfamethoxazole and trimethoprim (Kuemmerer, 2009; Neela et al., 2007; Tendencia and de la Pena, 2001; Torrella et al., 2003; Turkdogan and Yetilmezsoy, 2009; Zhang et al., 2009). Such antibiotic resistance bacteria have been found in coastal waters impacted by sewage water (Kimiran-Erdem et al., 2007; Kuemmerer, 2004; Neela et al., 2007) and can potentially be transmitted from sewage lagoons and dump sites into the communities and impose an even greater health risk (Chambers et al., 2008).

4.2 Benzotriazoles

Benzotriazoles is one of the ubiquitous compounds used in corrosion products, rubber material, UV stabilizers and in household cleaning products. Despite the universal use of these organic compounds, their ecotoxicology effect on surface water quality or aquatic life has not been studied in detail. However, many triazoles are reported to be fungicides and studies have demonstrated that triazoles have the ability to disrupt the endocrine system in aquatic organisms and mammals (Taxvig et al., 2007). The concentration levels detected in rural leachate impacted surface waters and raw sewage lagoon for the selected compounds Benzotriazole (BT) and 4&5-Methylbenzotriazole (TT) were up to 4.09 μg L^{-} (BT) and 0.88 μg L^{-} (4 & 5-TT). While control surface water samples obtained from undisturbed sites indicated no presence of TT; BT was found in all tested samples with concentration ranged between 0.02 - 0.09 μg L^{-}. The presence of BT in all controls may suggest that either the controls were polluted through different activities (e.g. ATV and airplane traffic) or can be attributed to the high solubility of BT in water, which enhances offsite migration during snow melt and flood events.

In contrast to observed concentrations in rural waste facilities impacted waters, a comprehensive study performed in the Netherlands to determine benzotrialzoles in effluents of two sewage treatment plants, surface waters and drinking water samples found maximum concentration levels for BT of 8.0 μg L^{-} and for methyl-1H-benzotriazole of 3.0 μg L^{-1} (summed concentration of two isomers) in wastewater effluent, between 0.1-1.0 μg L^{-1} in surface, and 0.01 -0.2 μg L^{-1} drinking water (Leerdam et al., 2009). Hagedorn et al. (2013) observed concentrations levels up to 0.31 μg L^{-1} for BT and 4.49 μg L^{-1} for 4-5, TT study conducted in Anchorage Alaska municipal creeks

and snowmelt runoff. These studies indicate the pervasive abundance of these compounds and their vast distribution in the environment.

4.3 Phthalates

Of particular environmental concern for rural Alaska subsistence foods and freshwater are the detected phthalate metabolites (DEP, DEHP, DNOP, DBP, and BBP), which are known to act as an endocrine disruptor and carcinogens in mammal and aquatic organisms (Teuten et al., 2009; vom Saal et al., 2010). The concentration levels detected for phthalate metabolites in solid waste impacted surface waters and raw sewage samples are 8.04 μg L^{-} for DBP, 5.51 μg L^{-1} for DEHP, 4.05 μg L^{-1} for DEP, 2.24 μg L^{-1} for DNOP, and 1.45 μg L^{-1} BBP. While these concentrations are substantial for a remote site with low occupancy, they are low compared to concentrations identified in eight different landfill sites (Sweden, Italy and Germany) of various ages with concentrations of:: DMP 300 μg L^{-}, DEP 540 μg L^{-}, DBP 23 μg L^{-}, BBP 7 μg L^{-}, and DEHP with 460 μg L^{-} (Mersiowsky et al., 2001).

All phthalate compounds were observed in all tested controls and only DEP was not detected in the dump drainage waters. The concentrations found in control sites may indicate that these phthalates may not entirely be attributed through leaching of local dump and sewage sites but may also be contributed through atmospheric transport of nano-particulate plastic palettes followed by leaching (Teuten et al., 2009). Another alternative source of distributing phthalates into adjacent surface water bodies is open burning of trash, a common method of waste reduction in rural communities.

5. Conclusions

This study intended to provide a first step in characterizing of wastewater and solid waste derived organic pollutants and their potential impacts on freshwater systems in the vicinity of rural Alaska waste sites. For all tested rural Alaska landfill leachate and raw sewage samples, HPLC-MSMS analysis revealed the presence of pharmaceuticals (sulfamethoxazole, trimethoprim, ibuprofen and Tylenol, bupropion, caffeine and 1,7-dimethylxanthine), benzotriazole and 4&5-methylbenzotriazole, and phthalate metabolites (DEP, DEHP, DNOP, DBP, and BBP). The detected organic pollutants provide evidence that direct discharge or leaking rural Alaska waste facilities are sources of XOCs, and their respective concentration levels can be detected by HPLC-MSMS analysis. Moreover, the study highlights that sanitation conditions and practices of minimal or no treatment to their wastewater, along with poorly maintained or leaking sewage lagoons and septic tanks, or uncontrolled and untreated leachate discharge could potentially impact surface water quality.

The result of this study highlights the need for further and more comprehensive studies to assess XOC's emission from rural Alaska waste facilities. At this time, we lack information to achieve a better understanding regarding XOCs transport processes, toxicological impacts posed to human and environmental health, and their ability to persist in the environment in cold regions.

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7. Figures

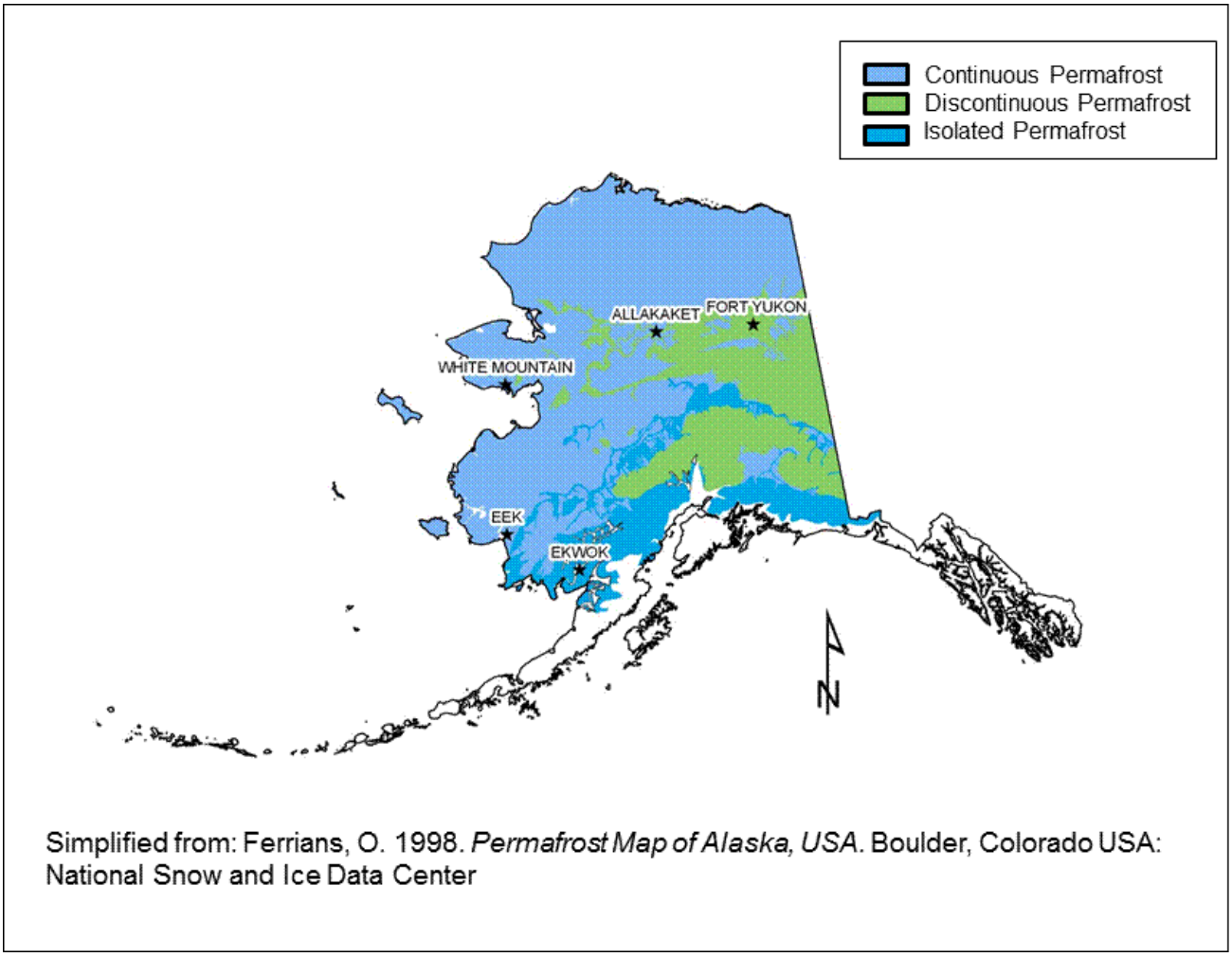


Figure IV-1: Rural Alaska communities and their representative regions

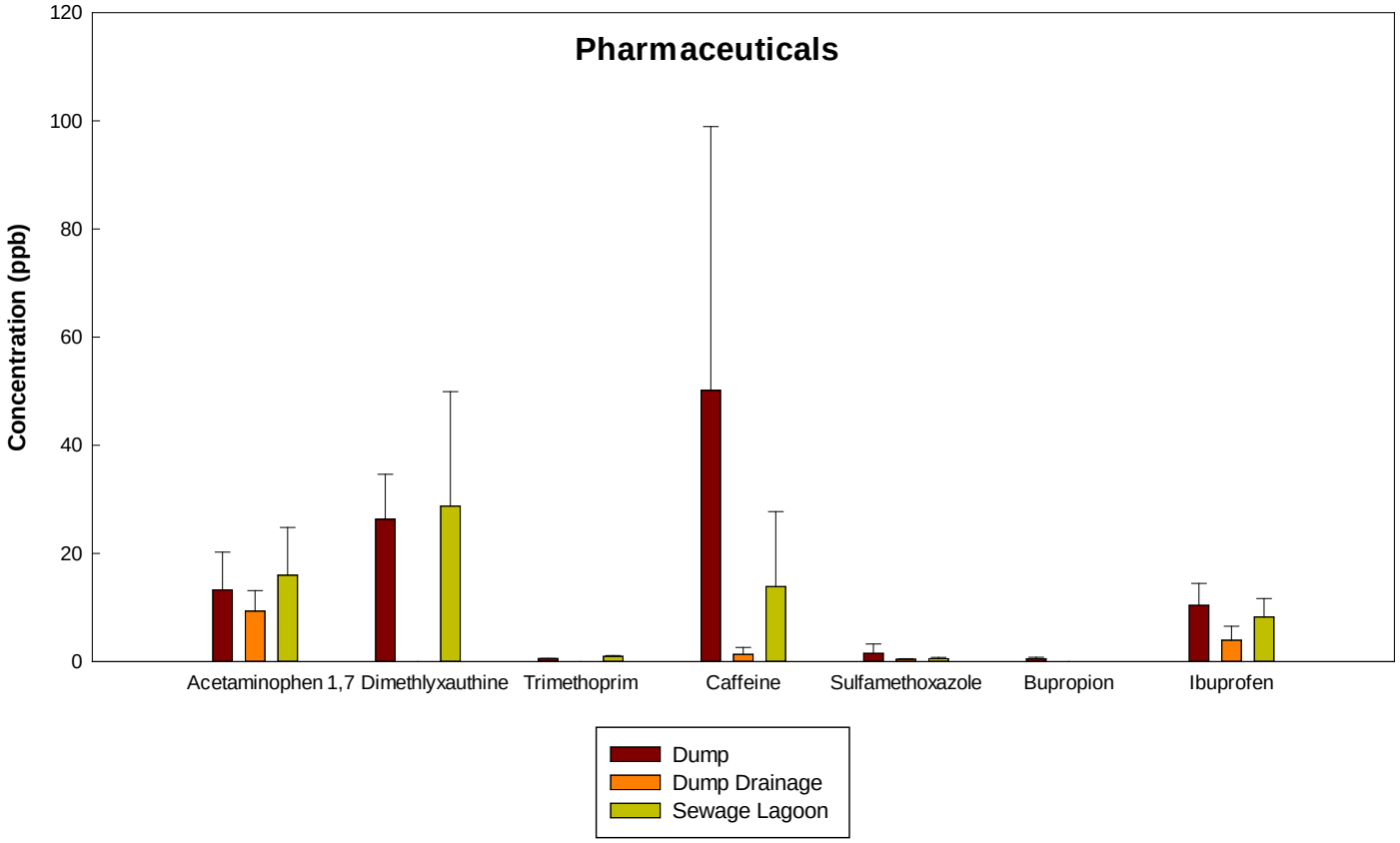


Figure IV-2: Concentrations of analyzed pharmaceuticals in rural Alaska impacted leachate and raw sewage samples, no pharmaceutical was found in the control sites. The error bars represent the 95% confidence interval.

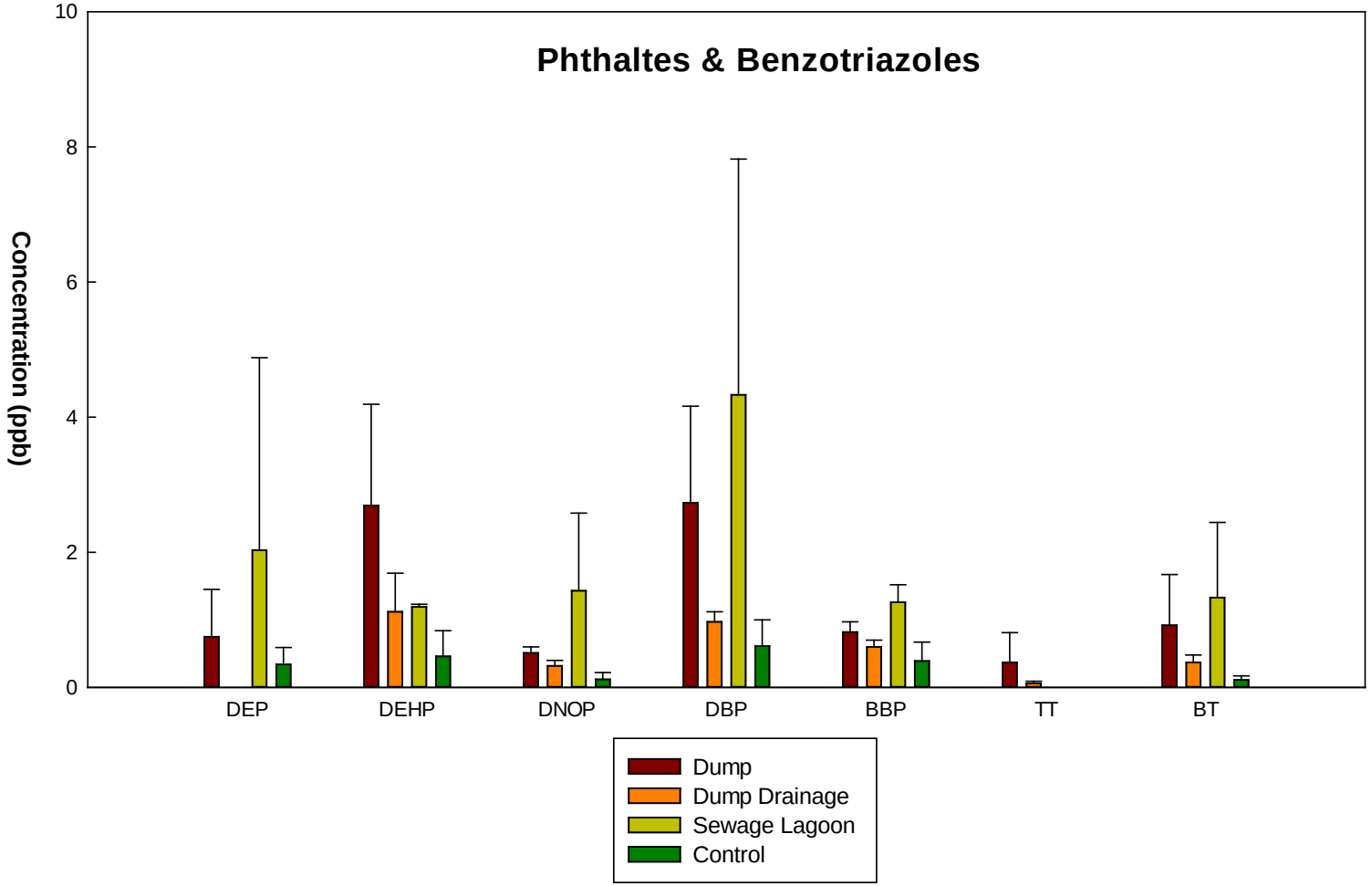


Figure VI-3: Concentrations of *p*hthalates and benzotriazoles in rural Alaska impacted leachate and raw sewage samples and control sites. The error bars represent the 95% confidence interval.

8. Tables

Table IV-1: Organic pollutants and their characteristics in waste impacted surface water samples

No.	Compound	formula	MW	pka	typical use
1	Sulfamethoxazole	$C_{10}H_{11}N_3O_3S$	253.28	5.7	antibiotic
2	Trimethoprim	$C_{14}H_{18}N_4O_3$	290.32	7.12	antibiotic
3	Lincomycin	$C_{18}H_{34}N_2O_6S$	406.54	12.9	antibiotic
4	Enrofloxacin	$C_{19}H_{22}FN_3O_3$	359.40	8.90	antibiotic
5	Carbamazepine	$C_{15}H_{12}NO_2$	236.20	13.94	anticonvulsant
6	Venlafaxine	$C_{17}H_{27}NO_2$•HCl	313.86	9.40	antidepressant
7	Sertraline	$C_{17}H_{17}$NCl•HCl	342.69	9.8	antidepressant
8	Bupropion	$C_{13}H_{18}$ClNO•HCl	276.20	8.25	antidepressant
9	Ibuprophen	$C_{13}H_{18}O_2$	206.28	4.91	anti-inflammatory
10	Acetaminophen	$C_8H_9NO_2$	151.17	9.9	antipyretic
11	1,7 Dimethylxanthine	$C_7H_8N_4O_2$	180.16	10.7	caffeine metabolite
12	Cotinine	$C_{10}H_{12}N_2O$	176.22	8.80	nicotine metabolite
13	Erythromecin-H_2O	$C_{37}H_{67}NO_{13}$•H_2O	751.93	8.80	Erythromecin metabolite
14	Caffeine	$C_8H_{10}N_4O_2$	194.19	10.4	stimulant
15	1H-Benzothriazole	C_7H_5NS	119.12	8.2	anticorrosive, plastic stabilizer
16	4,5 Methylbenzotriazole	$C_7H_7N_3$	133.15	8.7	anticorrosive, plastic stabilizer
18	Dimethyl phthalate	$C_6H_5(CO_2CH_3)_2$	194.18	2.89, 5.51	plasticizer and stabilizer
19	Diethyl phthalate	$C_6H_4(CO_2C_2H_5)_2$	222.24	NA	plasticizer and stabilizer
20	Dibuthyl phthalate	$C_6H_4[CO_2(CH_2)_2CH_3]_2$	278.34	NA	plasticizer and stabilizer
21	Benzyl butyl phthalate	$CH_3(CH_2)_3O_2C_7H_4CO_2C_7H_7$	312.36	NA	plasticizer and stabilizer
22	Diethylhexyl phthalate	$C_6H_4[CO_2C_2H_3(C_2H_5)C_4H_9]_2$	390.56	NA	plasticizer and stabilizer
23	Di(n-octyl) phthalate	$C_6H_4[CO_2(CH_2)_7CH_3]_2$	390.56	NA	plasticizer and stabilizer

***** NA : Not Available; Sources: Staples et al., 1997; Wang and Barlaz, 1998; Karlsson et al., 1999; Oman, 2001

Table IV-2: *Sample number and location of collected surface waters and raw sewage samples*

	LOCATIONS			
OrganicCompounds	**Impacted Surface Water**	**Raw Sewage**	**Control**	**Total**
Phthalates	8	3	5	16
Pharmaceuticals	13	6	7	26
Benzotrialzole	13	6	7	26

Table IV-3: LC-MSMS HPLC-MSMS Instrumentation Method

Compound Name	**Precursor mass ($M-H^+$)**	**Product Ions ($M-H^+$)**		**Fragmentation Voltage**	**Collision Energy**
		Quantifier	Qualifier	(V)	(V)
Dimethyl phthalate (DMP)	163	92	77	130	30
Diethyl phthalate (DEP)	223	149	177	70	10
Di-n-butyl phthalate (DBP)	279	149	205	75	5
Benzyl butyl phthalate (BBP)	313	149.1	91	85	15
Diethylhexyl phthalate (DEHP)	391	149.1	167	90	10
Di-n-octyl phthalate (DNOP)	391	261.1	149	110	7
Dibutyl phthalate-d4 (DBP-d4)	281	153	209	80	5
Diethylhexyl phthalate-d4 (DEHP-d4)	395	153	171	100	10
Diethyl phthalate-d4 (DEP-d4)	277	181	153	70	10
Sulfamethoxazole	254	92	65	90	26/50
Trimethoprim	291	123	110	135	34
Lincomycin	407	126	42	120	30/88
Enrofloxacin	360	342	286	110	24/36
Carbamazepine	237	194	179	115	20/20
Carbamazepine C13N15	239	193	167	120	41/37
Venlafaxine	278	121	58	90	30/16
Sertraline	306	275	159	75	10/24
Bupropion	240	130	77	95	60/72
Ibuprofen	205	161		60	1
Ibuprofen-d3	208	164		90	3
Acetaminophen	110	152	65	110	25/32
1,7 Dimethylxanthine	181	69	55	110	32
Cotinine	177	98	80	115	30
Cotinine-d_3	180	101		115	30
Erythromecin-H_2O	734	158	83	195	34/62
Caffeine	195	138	42	115	28/38
Caffeine-d3	198	140	43	115	29/40
1H-Benzothriazole (BT)	120	92	65	125	20/25
1H-Benzothriazole-d4 (BT-d4)	124	96	69	125	20/25
4,5 Methylbenzotriazole (4-5 TT)	134	134	79	77	20/35
5,6-Dimethylbenzotriazole	148	148	77	130	35

*LC MS/MS methods were developed: for benzotriazole constitutes by Hagedorn et al., 2013, pharmaceutical constitutes Ede 2012 and phthalates constitutes by Ali et al., (in review).

Table IV-4: Concentrations (ppb) for pharmaceutical, benzotriazole and phthalate compounds detected in waste impacted waters

		Waste Impacted Surface Waters									
					Waste Impacted Surface Waters			Landfill	Landfill Drainage	Sewage Lagoon	Control Waters
					Concentration Levels (ppb)						
No.	Compound	n	LOD	LOQ	Minimum	Maximum	Mean	Mean	Mean	Mean	Mean
1	Sulfamethoxazole	26	0.04	0.13	0.22	4.95	1.06	1.50 ± 2.19	0.42 ± 0.13	0.52 ± 0.08	N/D
2	Trimethoprim	26	0.05	0.14	0.52	1.08	0.75	0.54 ± 0.03	N/D	0.96 ± 0.17	N/D
3	Bupropion	26	0.03	0.1	0.23	0.84	0.53	0.53 ± 0.31	N/D	<LOD	N/D
4	Ibuprophen	26	0.04	0.11	0.33	16.96	5.19	10.40 ± 5.79	3.94 ± 0.21	8.23 ± 4.27	N/D
5	Acetaminophen	26	0.03	0.09	1.21	26.87	14.95	13.25 ± 6.98	9.31 ± 5.81	15.97 ± 10.07	N/D
6	1,7Dimethylxanthine	26	0.04	0.12	2.34	53.71	27.65	26.31 ± 7.12	<LOD	28.73 ± 24.15	N/D
7	Caffeine	26	0.04	0.12	0.24	112.4	22.98	50.14 ± 51.14	1.32 ± 2.16	13.86 ± 15.81	N/D
8	4&5 Methylbenzotriazole (TT)	26	0.04	0.06	N/D	0.88	0.25	0.37 ± 0.44	N/D	0.06 ± 0.003	N/D
9	Benzotriazole (BT)	26	0.04	0.07	N/D	4.08	0.76	0.92 ± 1.22	0.37 ± 0.10	1.33 ± 1.39	0.11 ± 0.06
10	Diethyl phthalate (DEP)	16	0.01	0.03	N/D	4.05	2.35	0.74 ± 1.14	<LOD	2.03 ± 2.85	0.42 ± 0.26
11	Diethylhexyl phthalate (DEHP)	16	0.01	0.04	N/D	5.51	1.85	2.69 ± 1.72	1.12 ± 0.58	0.71 ± 0.71	0.70 ± 0.47
12	Di-n-octyl phthalate (DNOP)	16	0.01	0.04	N/D	2.24	0.5	0.51 ± 0.11	0.20 ± 0.20	1.43 ± 1.14	0.16 ± 0.14
13	Di-n-butyl phthalate (DBP)	16	0.01	0.03	N/D	8.04	1.78	2.73 ± 1.63	0.97 ± 0.16	4.58 ± 4.89	0.61 ± 0.40
14	Dimethyl phthalate (DMP)	16	0.004	0.03	N/D	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
15	Butylbenzyl phthalate (BBP)	16	0.01	0.03	N/D	1.45	0.38	0.82 ± 0.15	0.38 ± 0.25	1.26 ± 0.26	0.57 ± 0.19

* Instrumentation quantification for pharmaceutical, benzotriazole, and phthalates species were calculated based on a 6 level calibration using the specific internal standards described above**.** The limit of detection (LOD) for each compound was calculated based on the standard deviation of the response (SD) and the slope of the calibration curve (S) according to the formula: LOD = 3.3*(SD/S). The limit of quantification (LOQ) calculation method was performed according to the formula: LOQ = 10*(SD/S). The compound concentration standard deviation was calculated based on 95% confidence level.

**N/D - not detected and LOD below HPLC-MS/MS detection limit

*** n.a. - no data are available

Chapter V

General Conclusion

This research was conducted to assess the status of waste management practices in rural Alaska communities. Two general questions were examined 1) what are typical composition and concentrations of waste-derived pollutants in and around rural Alaska waste sites, and 2) what are the major transport pathways that may impact migration of waste-derived pollutants now and in the future. This study focused on three broad categories of pollutants, including heavy metals, pathogen indicator organisms, and xenobiotic organic compounds. The research findings were described in three chapters 1) assessment of heavy metal leachate in rural Alaska solid waste sites, 2) the partitioning and transport behavior of pathogen indicator organisms in cold regions waste sites, and 3) detection of organic pollutants in rural Alaska landfills and wastewater systems. The most significant findings for each individual Chapters are listed below:

Chapter 1) heavy metal leachate in rural Alaska solid waste sites

- Enrichment factors (EFs) in surface and subsurface waters at the landfills and at offsite locations within 50 meters down-gradient of the landfills were elevated in Co, Cu, Ni, Mn, Zn, Fe, Cr, Cd, and Pb.
- The mean EFs for waste impacted soils were significantly enriched in Pb and Cd.
- Metals were shown to leach from soils and solid waste materials into surface water preferentially during seasonal high water events such as snowmelt and heavy rain.
- The detected metal concentrations are high enough to potentially impact rural communities' traditional drinking water and subsistence food resources, and may increase due to climate-related hydrologic changes in the future.

Chapter 2) the partitioning and transport behavior of pathogen indicator organisms in cold regions waste sites

- *E. coli* and *Enterococcus sp.* tend to preferentially attach and migrate with soil particles in surface waters, and are frequently transported offsite during snowmelt runoff.
- *Enterococcus sp.* was observed to have higher and more sustained viability in cold environmental conditions, and therefore may be a more suitable indicator organism compared to *E. coli* for cold climate regions.
- Waste sites in rural communities were found to transmit *E. coli* and *Enterococcus sp*. into nearby water resources.

Chapter 3) the detection of organic pollutants in rural Alaska landfills and wastewater system

- HPLC-MSMS analysis revealed the presence of pharmaceutical (sulfamethoxazole, trimethoprim, ibuprofen and acetaminophen, bupropion, caffeine and 1,7-dimethylxanthine), benzotriazoles (1 H-benzotriazole (BT) and 4&5-methylbenzotriazole (tolyltriazole TT), and phthalates (DEP, DEHP, DNOP, DBP, DMP and BBP) in tested rural Alaska landfill leachate and raw sewage samples.
- The concentration levels detected were similar or lower in and around traditional landfills and sewage lagoons compared to modern constructed landfills and wastewater treatment effluents.
- The detected organic pollutants are evidence that direct discharge or leaking rural Alaska waste facilities are sources of XOCs, and their respective concentrations levels can have a considerable impact on surface water quality.

The results of this research indicate that the current waste disposal practices are not sufficient to prevent offsite migration of waste-derived pollutants and guarantee human and environmental health now and in the future. The observed proliferation of heavy

metals, pathogen indicator organisms and xenobiotics indicates that waste management facilities and practices could potentially have an impact on surface water quality proximal to rural Alaska waste facilities.

The results highlight the relevance of further and more comprehensive studies to assess waste derived pollutant emissions caused by direct or indirect discharge of water from rural Alaska waste facilities. As surface waters proximal to rural Alaska communities are closely linked to food and drinking water sources, contamination through leaching of open dumps and sewage lagoons can potentially impact human health.

The results of this study strongly recommend enhancement management practices to reduce this risk. Furthermore, our research findings highlight the need to apply state regulations to remove potentially hazardous components from rural Alaska wastewater and municipal solid waste streams. Finally, there is a need to establish solid waste and wastewater leachate monitoring and assessment practices for active and closed rural Alaska waste sites.

Appendix A: Sample Locations Background and Site Description

A-i: Allakaket

Allakaket is a small federally recognized tribe with a population of 190 residents. The Athabascan community is located approximately 306 km northwest of Fairbanks, Alaska on the south bank of the Koyukuk River (Census, Bureau, 2010). Subsistence hunting and fishing are the primary food source. Allakaket is underlain by Koyukuk terrain composed of unconsolidated Quaternary deposit of plutonic rock and deep bedrock rock unit (Hamilton, 1969). The region is encountered with eolian and lacustrine soil material, which is composed of a fine clay-silt-sand and organic sedimentation (Hamilton, 1969), and overlies permafrost observed at approximately 15 m below ground surface (bgs) (Timothy et al., 2000). The climate is characterized by a cold, continental climate with extreme temperature ranging between of -57°C to 34°C, with an average freeze-free period of 64 days, and has an average of 604.2 mm in rain and 22.4 cm of snowfall (Shulski and Wendler, 2007).

Most public facilities and community's homes were severely damaged in the 1994 Koyukuk River flood. Most of the damaged homes were replaced, including a constructed underlined sewage lagoon and a drinking water treatment plant. Domestic drinking water is supplied by treated Koyukuk River water at the community washeteria (Patterson et al., 2012). Only the community school, school housing and washeteria are connected to in-home pluming for water and wastewater. Individual households are hauling their drinking water from the washeteria or from traditional drinking water resources. Households' wastewater is discharged directly onto the tundra or into local tundra ponds. Honeybuckets and pit privies are used for human waste. At the community six wells were identified using historic well logs. These well logs indicate that silt and gravel are encountered at depths up to 21 m bgs before a bedrock layer and a shallow aquifer is observed approximately 6 m bgs (ADCCED; ADNR, 2009).

The community of Allakaket received Indian Environmental General Assistance Program funding sponsored by the Environmental Protection Agency (EPA) to establish an environmental program. With respect to solid waste, the community is currently in the progress to complete a solid waste management plan, therefore no management practices are instated for solid waste separation or segregation such as recycling and backhauling, public access restriction, or soil

cover material application. Due to unrestricted public access and a broken burnbox, uncontrolled open burning of waste material is commonly performed on ground at the dump site. During the dump site visits, observations were made of many animal carcasses disposed and the presence of demolition and construction material were also detected. This above-ground dump site is approximately 10 years old with the dimension of 0.01 km^2 dump site and is constructed on an upland area along a ridge approximately 1.2 km from the village area (Figures A.i-2). The dump site is characterized by shallow permafrost (0.3-1.2 m) and saturated tundra. A natural drainage area is formed with a slope of 4% decline to the south. The lowland area at the dump site is covered with woody peat tundra vegetated with Sphagnum moss, cottonwood, tussocks, and other sedges, willow saplings, and stunted spruce. The highland area is typically vegetated with horsetail, grasses, Sphagnum moss, cottonwood and other sedges, Labrador tea, lowbush cranberries, blueberry, birch, alder, willow saplings, and black spruce. The village residents are concerned about natural drainage channels forming during spring break-up and the potential environmental impacts due to waste leachate.

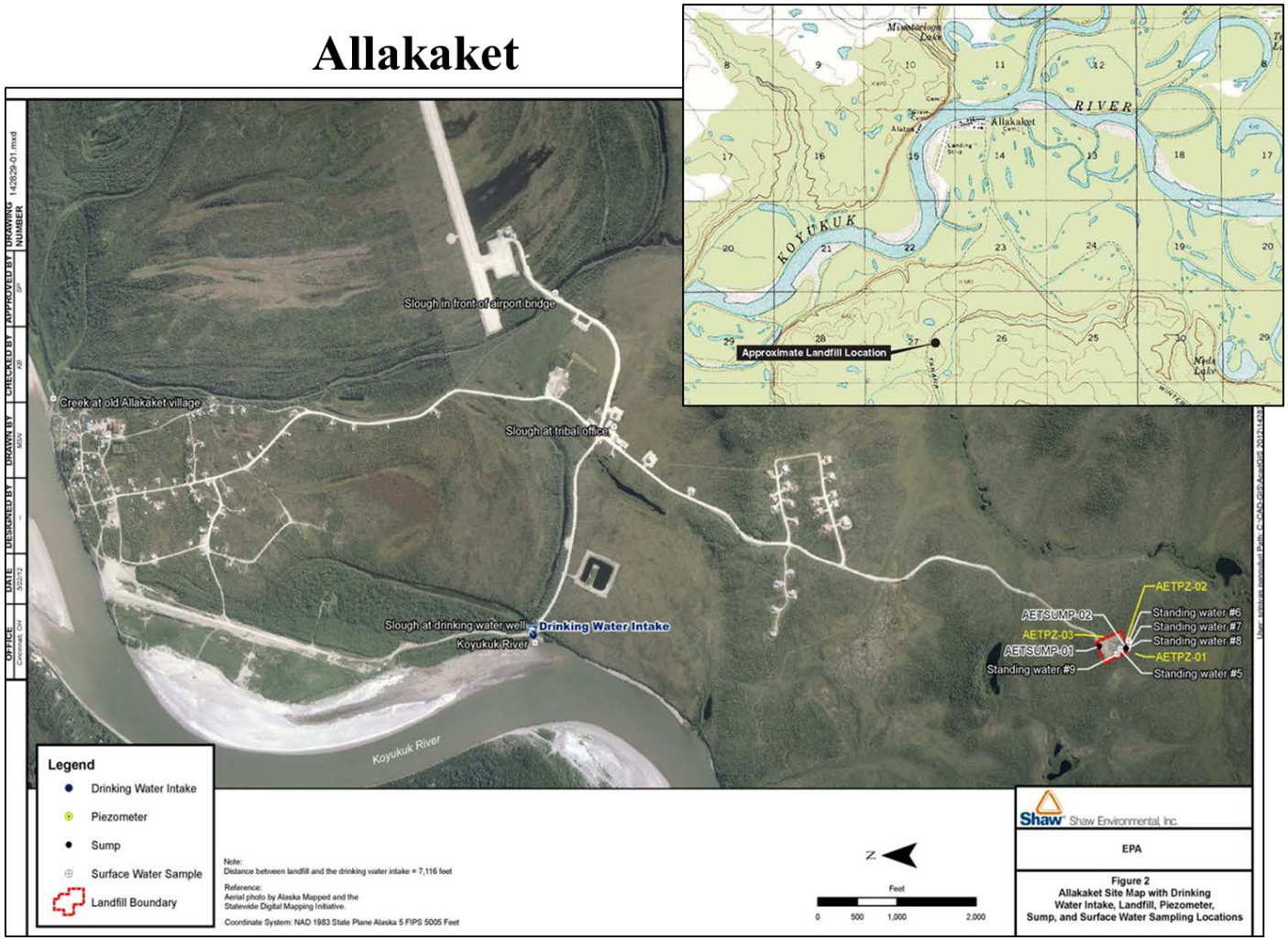
Figure A.i-1: Illustration of scope and extent Allakaket's dump condition

Table A.i-1: Sampling collection date and on-site field locations

Date*	Sample Location	GPS	Elevation
a,c	Standing water Dump left - D1	N 66° 31.702' W 152° 39.329'	184m
a,c	Standing water Dump mid-left - D2	N 66° 31.727' W 152° 39.892'	185m
a,c	Standing water mid Dump - D3	N 66° 31.719' W 152° 39.868'	183m
a,c	Standing water lowland right - D4	N 66° 31.704' W 152° 39.866'	181m
a,c	Standing water lowland left - D5	N 66° 32.724' W 152° 39.812'	182m
a	Drinking Water-Washeteria	N 66° 32.925' W 152° 39.669'	134m
a	Slough behind tribal office	N 66° 32.860' W 152° 38.723'	140m
a,c	Koyukuk River	N 66° 32.933' W 152° 39.772'	127m
a,c	Koyukuk /Drinking Water Well	N 66° 32.939' W 152° 39.711'	132m
a,c	Airport-Slough/ Old Dump-Site	N 66° 32.876' W 152° 38.062'	134m
a,c	Airport-Slough	N 66° 33.893' W 152° 38.442'	134m
a	Slough outlet into Koyukuk River	N 66° 32.953' W 152° 38.539'	136m
b	AEK_Sump_01	N 66° 31.810' W 152° 39.804'	184m
c	AEK_Sump_02	N 66° 31.902' W 152° 39.819'	182m
c	AEKPZ-01	N 66° 31.898' W 152° 39.817'	182m
c	AEKPZ-02	N 66° 32.732' W 152° 39.799'	184m
c	AEKPZ-03	N 66° 31.812' W 152° 39.804'	185m

* Data for sample collection a) July 2010; b) June 2011, and c) August 2011

Allakaket


Slough in front of airport bridge
Creek at old Allakaket village
Slough at tribal office
Slough at drinking water well
Drinking Water Intake
Koyukuk River
Koyukuk River
AETPZ-02
AETSUMP-02
Standing water #6
Standing water #7
Standing water #8
AETPZ-03
AETSUMP-01
AETPZ-01
Standing water #9
Standing water #5
Approximate Landfill Location
Allakaket
KOYUKUK
RIVER
Legend
Drinking Water Intake
Piezometer
Sump
Surface Water Sample
Landfill Boundary
Note:
Distance between landfill and the drinking water intake = 7,116 feet
Reference:
Aerial photo by Alaska Mapped and the
Statewide Digital Mapping Initiative.
Coordinate System: NAD 1983 State Plane Alaska 5 FIPS 5005 Feet
N
Feet
0
500
1,000
2,000
Shaw Shaw Environmental, Inc.
EPA
Figure 2
Allakaket Site Map with Drinking
Water Intake, Landfill, Piezometer,
Sump, and Surface Water Sampling Locations

A-ii: Eek

Eek, a federal recognized tribe of Yup'ik Eskimo community has a population of 286 residents. The community is located on the south bank of the Eek River, 19 km east of the mouth of Kuskokwim River and approximately 56 km south of Bethel on the Yukon-Kuskokwim Delta (Census, Bureau, 2010). The community of Eek is primarily subsistence-based with 80 - 90% of their diet consisting of salmon (all five Pacific salmon species spawn in the Eek River) (Census and Bureau, 2010). The region is characterized by alluvial and fluvial deposits of gravel, sand, silt and clay, overlying with igneous metamorphic and sedimentary rock units ranging in age from Ordovician to the Cretaceous eras (ADEC, 2011). Discontinuous permafrost is encountered mostly in the flats, which are portrayed with saturated tundra ground and many tundra ponds with only a few meters of elevation marking the boundaries of major drainages (ADEC, 2011). The historic well log search identified two wells within the Eek community. The well logs reported a static water depth range from 5 to 7 m bgs, as well as showed saltwater seepage at depths greater than 21 m (ADCCED; ADNR, 2009). The climate is characterized by an Alaskan west-central climate with temperature ranges of -44°C to 30°C; an average freeze-free period of 87 days, and an average of 406.4 mm in rain and 13.4 cm of snowfall (Shulski and Wendler, 2007).

The community derives water from Eek River for its primary domestic water supply source, which is treated and stored at the washeteria. Also utilized rain entrapment systems and ice melt for secondary portable drinking water sources. Only the community school, school housing and washeteria are connected to in-home plumbing for water and wastewater. Individual households haul their drinking water from the washeteria or from traditional drinking water sources. Households' wastewater is discharged directly onto the tundra or into the nearby sewage lagoon. Human waste is also discharged using honeybuckets into the traditional sewage lagoon.

In 1996 Eek received funding from the EPA to clean-up the solid waste site and the honeybucket lagoon. Prior to 1996, both waste sites were assessed by the Alaska Department of Environmental Conservation (ADEC) as highly vulnerable for microbial contamination. Additionally, Eek obtained Indian Environmental General Assistance Program funding sponsored by the EPA to establish an environmental program. The community implemented a recycling program for batteries and aluminum cans, and annual backhaul for electrical equipment such as TV's, washing machines, refrigerators etc. Furthermore, the community hired a solid waste operator for weekly

household waste collection, operating the burnbox, and assembling and packaging of residual burned and ash material into supersacks. For waste reduction most household waste is burned at the community burnbox located at the dump site twice a week. The filled supersacks are stored around the dump site as a wind-barrier to prevent unconsolidated waste from being blown away from the dump site. Currently, the community's residents have unrestricted public access to the dump site and honeybucket lagoon. Due to unrestricted public access uncontrolled open burning of waste material is commonly performed on ground at the dump site.

The approximately 33 year old ponded solid waste site is 0.07 km^2 in size and located adjacent to the community honeybucket lagoon. Both sites are less than 1.6 km away from the community and approximately 2.4 km away from the drinking water source and subsistence source (berry picking and fishing). The pollutant sources reportedly leach into two connected tundra ponds that are hydrologically connected to the Eek River (Patterson et al., 2012). Based on a reconnaissance of the waste sites, the groundwater system was determined to be complex and influenced by tides, surface water and topography. In addition, saturated tundra was reported with standing water around the waste sites year round but with no flooding (Patterson et al., 2012). The vegetation is characterized as Sphagnum moss, cottonwood, tussocks and other sedges, Labrador tea, lowbush cranberries and blueberry bushes at the sites. This community is highly concerned about exposure to microbial and chemical contamination from both waste sites due to the close location to traditional drinking water and subsistence food sources.

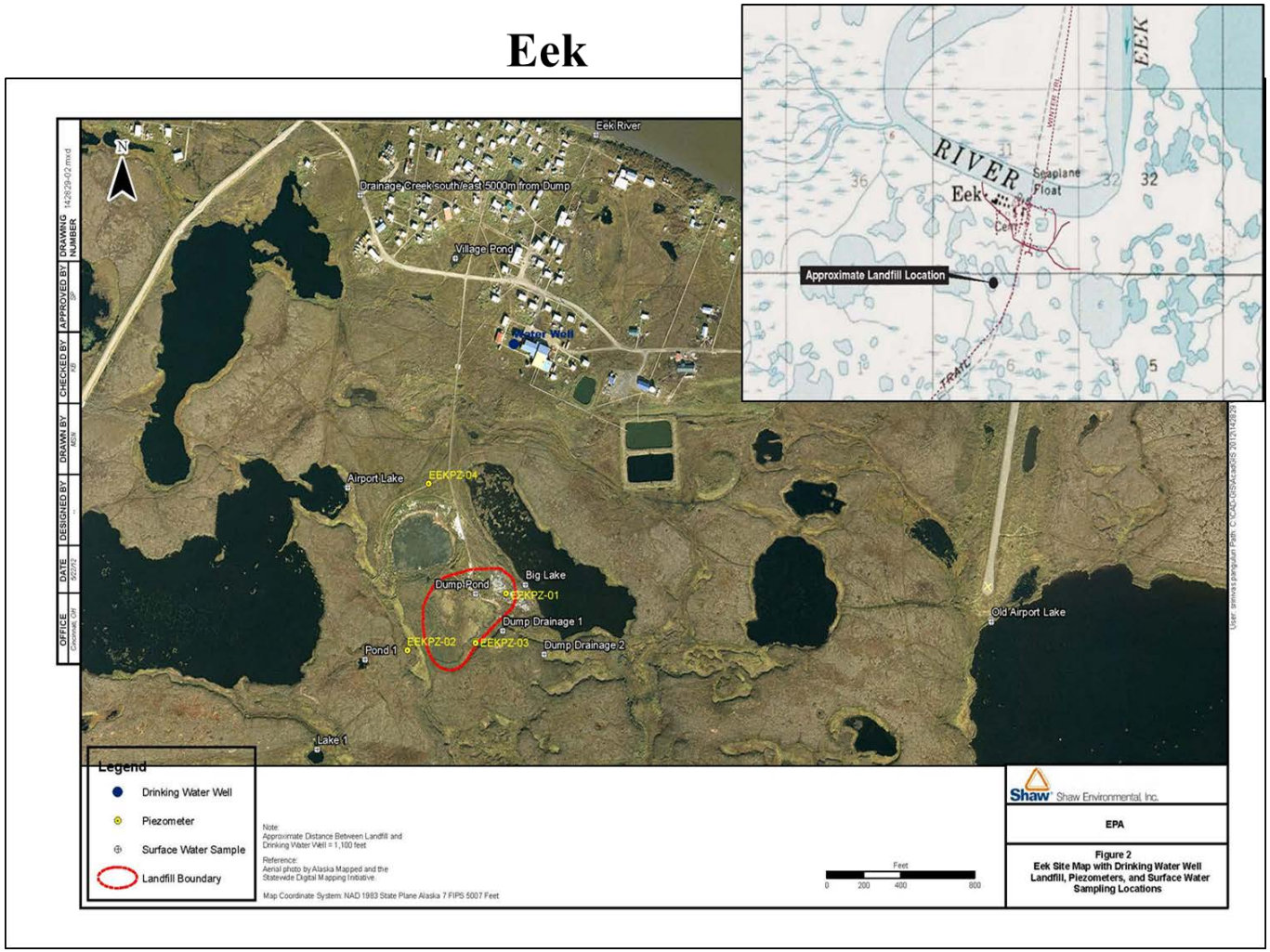
Figure A.ii-1: Illustration of scope and extent Eek's dump conditions

Table A.ii: Sample collection dates and on-site field locations

Date*	Sample Location	GPS	Elevation
a,c,d,e	Eek River	N60^{0}10.140' W162^0 01.515'	- 8m
a,c,d,e	Honeybucket Lagoon	N 60^{0}12.832' W162^0 01.892'	-5m
a	Tundra Lake	N 60^{0}12.602' W162^0 01.503'	+1m
a,b,c,d,e	Big Lake	N 60^{0}12.680' W162^0 01.886'	-11m
a,b,c,d,e	Airport Lake	N 60^{0}12.707' W162^0 01.904'	-3m
a,b,c,d,e	Dump Drainage	N 60^{0}12.736' W162^0 01.563'	+8m
a,b,c,d,e	Dump	N 60^o 12.751' W 162^o 01.641'	-8m
a,b,c,d,e	Village Creek	N 60^{0}13.197' W162^0 02.086'	-13m
b	Drinking Water - Washeteria		
e	Rain-Catchment/ Drinking Water		
b	Drinking/Ice Water		
b,c,d,e	Village Pond (mid-village/flood area)	N 60^{0}13.015' W162^0 01.700'	+3m
b,d	Tundra Pond -Old Runway ~ 1km	N 60^{0}12.704' W162^0 00.773'	+1m
e	EEKPZ-01	N 60^{0}12.486' W162^0 01.477'	-11m
e	EEKPZ-02	N 60^{0}12.445' W162^0 01.351'	+1m
e	EEkPZ-03	N 60^{0}12.437' W162^0 01.448'	+1m
e	EEkPZ-04	N 60^{0}12.440' W162^0 01.410'	+1m

* Data for sample collection a) August 2009, b) April 2010, c) October 2010, d) May 2011, and e) August 2011

Eek


Eek River
Drainage Creek South/east 5000m from Dump
Village Pond
Water Well
Airport Lake
EEKPZ-04
Big Lake
Dump Pond
EEKPZ-01
Dump Drainage 1
EEKPZ-02
EEKPZ-03
Dump Drainage 2
Pond 1
Lake 1
Old Airport Lake
Approximate Landfill Location
RIVER
Eek
Seaplane Float
EEK
Legend
Drinking Water Well
Piezometer
Surface Water Sample
Landfill Boundary
Note:
Approximate Distance Between Landfill and Drinking Water Well = 1,100 feet
Reference:
Aerial photo by Alaska Mapped and the Statewide Digital Mapping Initiative.
Map Coordinate System: NAD 1983 State Plane Alaska 7 FIPS 5007 Feet
Feet
0 200 400 800
Shaw Shaw Environmental, Inc.
EPA
Figure 2
Eek Site Map with Drinking Water Well Landfill, Piezometers, and Surface Water Sampling Locations

A-iii: Ekwok

Ekwok is a community with a population size of 130 residents is located along the Nushagak River, 69 km northeast of Dillingham and 302 km southwest of Anchorage (Census, Bureau, 2010). The inhabitants are a federal recognized tribe of Yup'ik Eskimo. The Ekwok community depends mostly on subsistence activities for various food sources such as salmon, moose, caribou, duck and berries. The coastal area is geological characterized by granitic and sedimentary rock units that date between the Ordovician and Cretaceous eras (Palcsak and Dorava, 1994). The alluvial, fluvial, and glacial soil deposits comprises of gravels, sands, silts, and clays, which extend at least 90 cm in depth (Glass, 1987). The soils are described as Nushagak and Hyer. Nushagak soils are featured as poorly drained acidic silt soil located at the south-facing slopes and highland area, which are generally frozen until midsummer. Hyer soil typically is present on north-facing slopes composed as poorly drained organic matter and peat and perennially frozen at depths of approximately 70 - 130 cm bgs (Rieger, 1965; Rieger et al., 1979). Ekwok is located in a climatic transition zone, a zone is primary influenced by maritime and continental climate with temperature range of -43°C to 29°C, an average freeze-free period of 134 days, an average of 140 mm in rain and 140.2 cm of snowfall (Shulski and Wendler, 2007).

Most of the community is served by 36 individual shallow domestic wells 2 to 3 m bgs. The community households are located more than 1 km away from the dump site. The nearest domestic well located approximately 0.4 km south away from the dump site is the newly constructed health clinic. Twelve wells were identified using historic well log search, which indicate a static water depths range from 0.9 to 3 m bgs. The logs show frozen ground is encountered at a depth of approximated 6 m bgs and groundwater was typically encountered at drilled depths greater than 6 to 10 m bgs (ADCCED; ADNR, 2009).

Residential homes are mostly equipped with sanitation systems including piped a septic system connected to a sewage lift station or a flush/haul system (DHHS, 1992). Sewage collection and wastewater hauling services is provided to the community weekly. Ekwok received Indian Environmental General Assistance Program funding sponsored by the

EPA to establish an environmental program. The community implemented a recycling program for batteries and aluminum cans, and annual backhaul for hazardous waste material such as electrical equipment such as TV's, washing machines, refrigerators etc. Furthermore, the community is in search for additional funding to expand their backhaul program for hazardous material including paints, unused and old heating and machinery oil, and construction material. The community has a solid waste operator, who is responsible for operating the burnbox and using machinery for waste compaction and soil cover application. Currently, there is no fence or infrastructure installed around the dump perimeter to control and restrict animal and public access. Due to unrestricted public access, uncontrolled open burning of waste material is commonly performed on ground at the dump site.

The 20 to 30 year old below ground dump site (trench-filling design) is located on excavated tundra approximately 2.4 km northeast upland of the community. The dump site is described with the dimension of 2.3 km^2 and 3-4.5 m deep, which is creating a 22% slope towards lowland area. During the site visit evidence of shallow soils of gravel, sand and silt and saturated tundra ground at the dump lowland area. The vegetation at the dump site is encompassed with Sphagnum mosses, lichens, tufted hair grass, low-bush blueberry and cranberries, willow saplings, Labrador tea, and black spruce. The highland area is covered with low-bush blueberry and cranberries, willow saplings, Labrador tea, birch and black spruce. No flooding or standing water issues were noticed in the past. The residents expressed concern regarding potential leachate from the open dump site into the shallow ground water system during spring snowmelt and rain runoff, hence a potential impact on the shallow drinking water wells (Patterson et al., 2012).

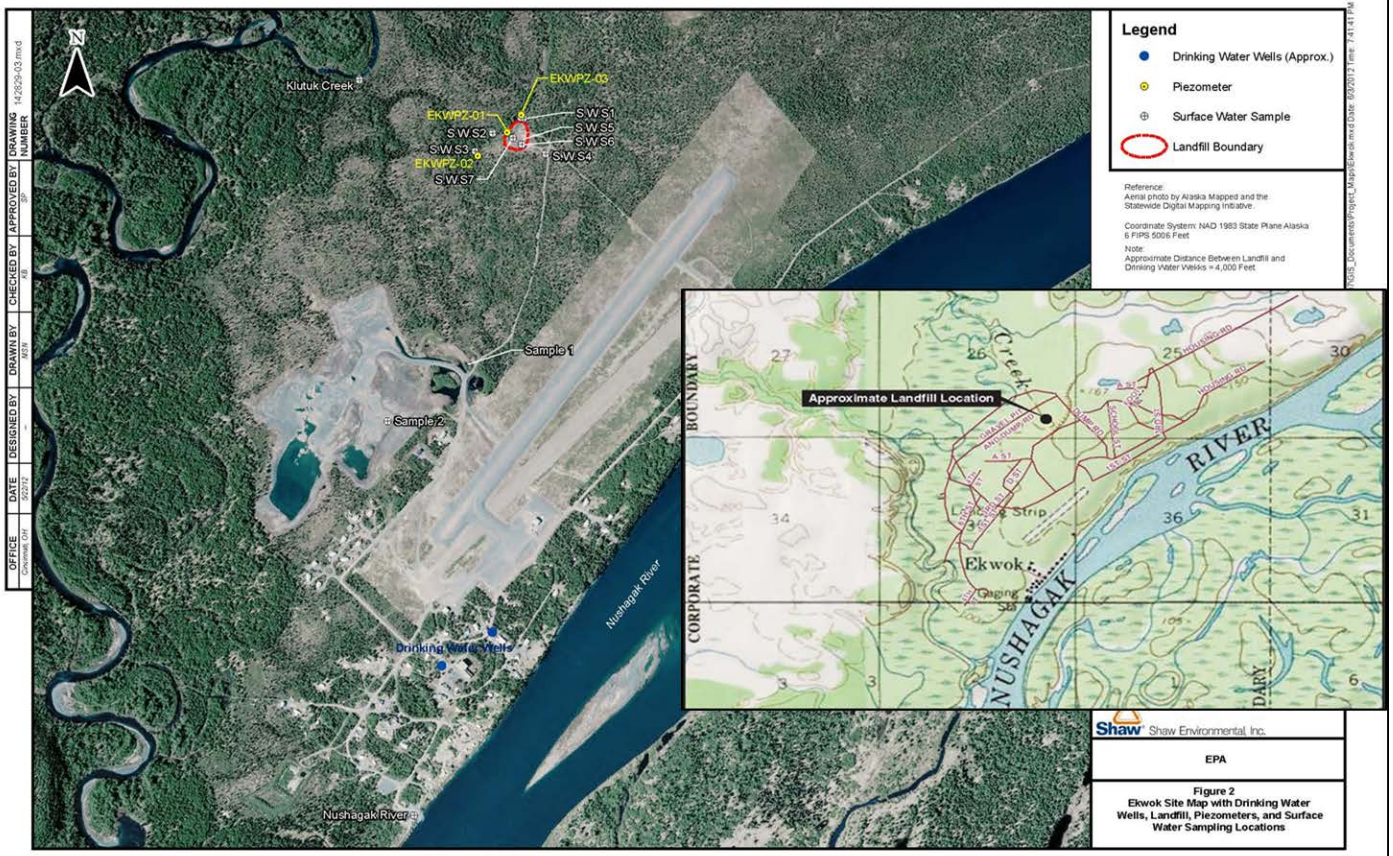
Figure Aiii-1: Illustration of scope and extent Ekwok's dump conditions

Table A.iii-1: Sample collection dates and on-site field locations

Date*	Sample Location	GPS	Elevation
a,b,c.d	Standing Water at Health Clinic	N 59° 21.738' W 157° 28.423'	34m
a,b.c	Klutuk Creek	N 59° 21.792' W 157° 28.859'	34m
b,c,d	Nushagak River	N 59° 20.785' W 157° 28.729	19m
a,b,d	Gravel Pit behind homes	N 59° 21.243' W 157° 29.046'	31m
a,b,c.d	Gravel Pit at Lagoon	N 59° 21.277' W 157° 29.031'	33m
b,c,d	Sewage Lagoon	N 59° 20. 838' W 157° 29.034	30m
d	Standing water at dump entrance -D1	N 59° 21.717' W 157° 28.396'	43m
d	Standing water at dump excess - D4	N 59° 21.689' W 157° 28.366'	39m
a,c	Standing water at EKWPZ-01	N 59° 21.738' W 157° 28.423'	34m
a,c	Standing water at EKWPZ-02	N 59° 21.702' W 157° 28.554'	34m
a,c	Standing water at EKWPZ-03	N 59° 21.713' W 157° 28.497'	35m
a,c	Standing Water at Dump Trench	N 59° 21.702' W157° 28.429'	46m
a,c	Standing Water Dump -D2	N 59° 21.708' W157° 28.433'	39m
a,c	Standing Water Dump -D3	N 59° 21.711' W157° 28.453'	39m
a,d	Home-Drinking Water Well		
c	ICAP Office-Well Water		
c	Health Clinic-Drinking Water		
a,b,c	EKWPZ-01	N 59° 21.750' W 157° 28.428'	34m
a,b,c,d	EKWPZ-02	N 59° 21.704' W 157° 28.559'	34m
a,b,c,d	EKWPZ-03	N 59° 21.712' W157° 28.454'	39m

* Data for sample collection a) April 2010, b) September 2010, c) May 2011, and d) August 2011

Ekwok


Klutuk Creek
EKWPZ-03
EKWPZ-01
S.W.S1
S.W.S2
S.W.S5
S.W.S6
S.W.S3
S.W.S4
EKWPZ-02
S.W.S7
Sample 1
Sample 2
Drinking Water Wells
Nushagak River
Legend
Drinking Water Wells (Approx.)
Piezometer
Surface Water Sample
Landfill Boundary
Reference:
Aerial photo by Alaska Mapped and the Statewide Digital Mapping Initiative.
Coordinate System: NAD 1983 State Plane Alaska 6 FIPS 5006 Feet
Note:
Approximate Distance Between Landfill and Drinking Water Wells = 4,000 Feet
Approximate Landfill Location
CORPORATE BOUNDARY
NUSHAGAK RIVER
Ekwok
Strip
Shaw Shaw Environmental, Inc.
EPA
Figure 2
Ekwok Site Map with Drinking Water Wells, Landfill, Piezometers, and Surface Water Sampling Locations

A-iv: Fort Yukon

Fort Yukon, a federally recognized tribe of Gwichyaa Zhee Gwich'in with a population of approximately 600 residents is located at the confluence of the Yukon River and Porcupine River approximately 233 km northeast of Fairbanks (Census, Bureau, 2010). Subsistence activities are an important component of the local culture and most residents rely on subsistence food. Fort Yukon operates as an emergency fire-fighting base and houses a former White Alice radar station for the U.S. Air Force. The community obtains its domestic water supply from two groundwater wells located in the village. The domestic water is tank-stored and treated before being supplied through a piped system to residents' homes. Residential homes are provided with piped sewage systems connected to lift stations and pumped to a newly constructed sewage lagoons located approximately 2.4 km east of town. Seven wells in Fort Yukon were identified using historic well log search. The well logs indicate that silt, sand, and gravel are encountered at depths up to 46 m bgs, underlain by lacustrine silts. Water was encountered at drilled depths ranging from 4 to 7 m bgs well log search (ADCCED; ADNR, 2009).

Fort Yukon is situated in the low-lying Yukon Flats region, which is characterized by vast areas of forested wetlands and bogs underlined by discontinuous permafrost. Vegetation observed at the region is commonly white and black spruce, tall and low shrubs, lichens, moss, grass, alder and white birch. The soil deposit is considered a thick accumulations primarily of alluvium, glacial, eolian composed of fine clay-loam, and gelisole consisting of mineral and organic soil material (Timothy et al., 2000). The different soil deposits are underlying with Cenozoic sedimentary composed of sandstone, siltstone, and shale rock unit (Timothy et al., 2000). The climate is characterized by a cold, continental climate with temperature range of -54°C to 33°C, an average freeze-free period of 64 days, an average of 304.8 mm in rain and 15.7 cm of snowfall (Shulski and Wendler, 2007).

Fort Yukon received Indian Environmental General Assistance Program funding sponsored by the EPA to establish an environmental program. The environmental program coordinator implemented recycling programs for batteries and aluminum cans and plastic bags are banned from local grocery stores. A specific constructed heating device is installed at the community center to utilize used heating and machinery oil. An annual backhaul program is instated for electrical equipment, old machinery, and used cars. Otherwise, no other waste separation or

segregation is implemented to manage hazardous waste such paints, construction or household maintenance material, unused cleaning products or old pharmaceutical products, etc. The solid waste program is overseen by the City of Fort Yukon. Solid waste collection and transfer to the dump is available for residents twice a week. Public access is still available for waste dumping. No fencing is installed to control and restrict animal or public access. Due to unrestricted public access uncontrolled open burning of waste material is commonly performed on ground at the dump site.

The approximately 30 year old, 0.02 km^2 above-ground dump site is located in an upland area 2.4 km from the community and approximately 300 m from the river system and berry trails. The dump site is situated along the edge of an old river bank 8-15 m higher than the lowland area, which is creating a 32% slope. Waste debris is pushed over the dump edge onto the lowland. The dump site border is distinguished by lowland area stretching in a north to south direction having the western side with a filled and covered sewage lagoon, and a stand of mixed forest (aspen, spruce, scrub willow and high grass) on the eastern side. At the lowland area, shallow soil consists of organic peat material and saturated tundra with underlining permafrost was encountered within 40 cm bgs. Currently the dump site is closed and covered with gravel; however a new permitted constructed landfill is in process. Meanwhile, waste material is disposed on the outside border of the dump site where and open burning takes place. The community expressed concerns regarding the dump waste composition of old military and construction waste, the elevation of the dump, and the natural drainage channel formed during strong water runoff events, which could result into migrating of hazardous waste leachate into the environment. A sign of potential waste leachate impact are visible with dying standing trees extending a distance of approximately 15-30 m of the dump area.

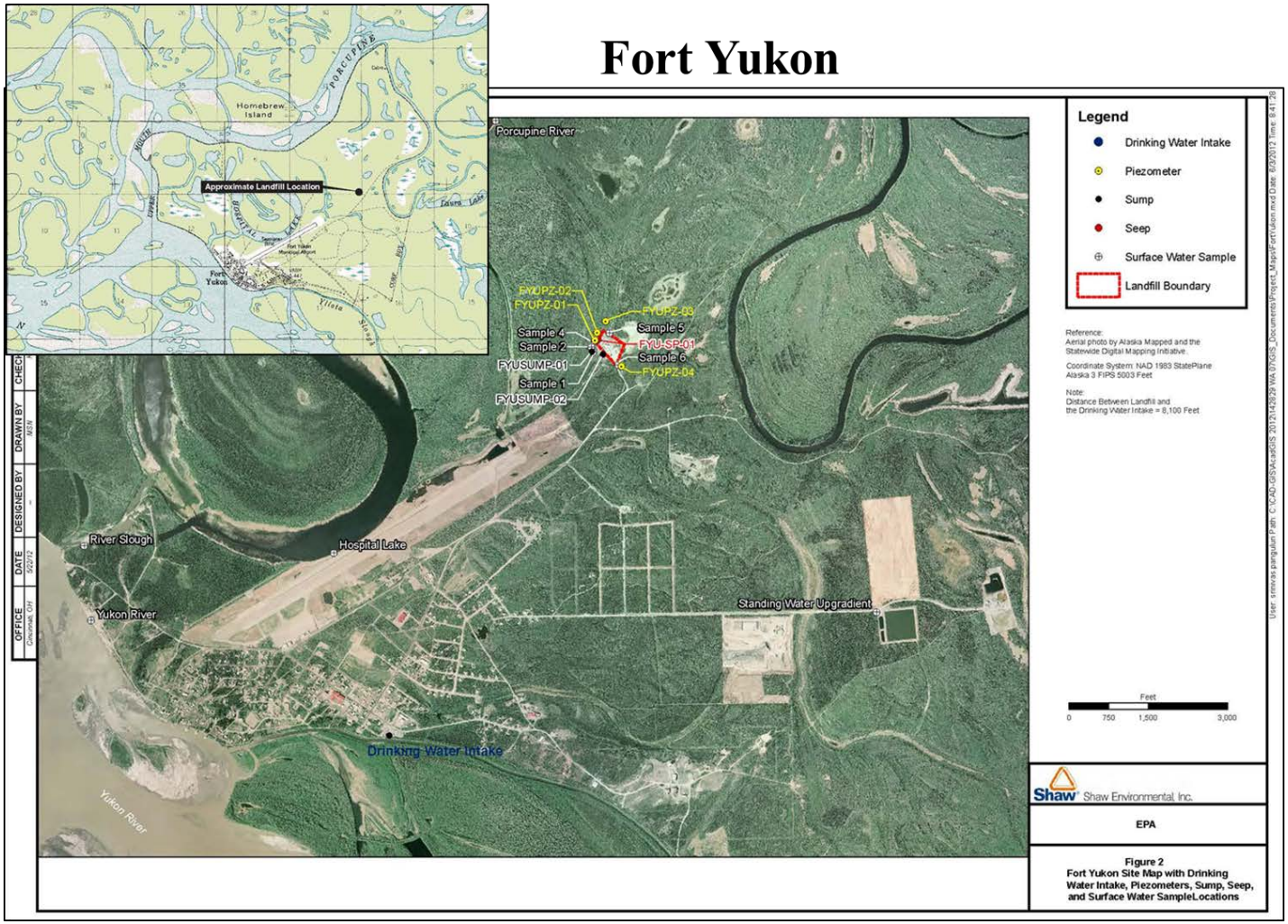
Figure A.iv-1: Illustration of scope and extent Fort Yukon's dump condition

Table: A.iv-1: Sample collection dates and on-site field location

Date*	Sample Location	GPS	Elevation
b,c	Standing Water Old Lagoon	N 66° 34.929' W 145° 12.926'	140m
b,c	Drainage Old Lagoon	N 66° 34.890' W 145° 12.991'	142m
a,b,c	Standing Water at FYWPZ-03	N 66° 34.914' W 145° 12.995'	128m
a,b,c	Standing Water at FYWPZ-02	N 66° 34.938' W 145° 13.085'	137m
a,b,c	Standing Water at FYWPZ-01	N 66° 34.929' W 145° 13.125'	130m
a,b,c	Standing Water Dump-D-1	N 66° 34.890' W 145° 12.991'	129m
a,b,c	Standing Water Dump-D-2	N 66° 34.929' W 145° 13.114'	138m
a	Porcupine River	N 66° 35.595' W 145° 13.368'	138m
a,c	Hospital Lake -Slough	N 66° 34.331' W 145° 13.112'	129m
a,b,c	Hospital Lake	N 66° 34.322' W 145° 13.260'	129m
a,b,c	Drainage New Sewage Lagoon	N 66° 34.123' W 145° 10.840'	142m
a,b,c	Yukon River	N 66° 34.938' W 145° 13.084'	133m
c	Sump1	N 66° 34.532' W 145° 13.129'	129m
c	Sump2	N 66° 34.532' W 145° 13.339'	129m
a,c	FYWPZ-01	N 66° 34.955' W 145° 13.178'	130m
a,c	FYWPZ-02	N 66° 34.855' W 145° 13.612'	137m
a,c	FYWPZ-03	N 66° 34.759' W 145° 12.591'	128m
a,c	FYWPZ-04	N 66° 34.812' W 145° 12.024'	140m

* Data for sample collection a) July 2010, b) May 2011, d) August 2011

Fort Yukon


Approximate Landfill Location
Homebrew Island
Porcupine River
FYUPZ-02
FYUPZ-01
FYUPZ-03
Sample 4
Sample 2
Sample 5
FYU-SP-01
Sample 6
FYUPZ-04
FYUSUMP-01
Sample 1
FYUSUMP-02
River Slough
Hospital Lake
Yukon River
Standing Water Upgradient
Drinking Water Intake
Legend
Drinking Water Intake
Piezometer
Sump
Seep
Surface Water Sample
Landfill Boundary
Reference:
Aerial photo by Alaska Mapped and the Statewide Digital Mapping Initiative.
Coordinate System: NAD 1983 StatePlane Alaska 3 FIPS 5003 Feet
Note:
Distance Between Landfill and the Drinking Water Intake = 8,100 Feet
Feet
0
750
1,500
3,000
Shaw Environmental, Inc.
EPA
Figure 2
Fort Yukon Site Map with Drinking Water Intake, Piezometers, Sump, Seep, and Surface Water SampleLocations

A-v: White Mountain

White Mountain, a federally-recognized tribe of Kawerak Eskimo with a population of approximately 224 residents is located on the Fish River 100 km east of Nome on the Seward Peninsula (Census, Bureau, 2010). Subsistence activities are prevalent in the community. The climate in the region is influenced by a transitional west coastal climate with temperature range of -48°C to 37°C, an average freeze-free period of 80 days, an average of 432 mm in rain and 17.3 cm of snowfall (Shulski and Wendler, 2007). The White Mountain region consists of alluvial and fluvial soil deposit composed of sand, silt, and gravel material, which are underlined with shallow outcroppings of Ordovician and Devonian sedimentary rock units. The region is distinguished with shallow permafrost and wet tundra; however, south-facing slopes were identified with the presence of discontinuous permafrost below the vegetative layer (Chambers et al., 2007).

The community obtains its treated domestic water supply from groundwater wells located in the village. The majority of the community is connected to the piped water and sewer system even so 25% of residents' still haul honeybuckets for human waste and wastewater. Two wells in White Mountain were reported using a historic well log search. The well logs reports described static water depths range between 8 to 27 m bgs, groundwater is encountered in the fractured limestone at depths greater than 6 m bgs, and a permafrost depths at least 2 m in the summer (ADCCED; ADNR, 2009).

White Mountain received Indian Environmental General Assistance Program funding sponsored by the EPA to establish an environmental program the past five years. The environmental program coordinator implemented recycling programs for batteries, aluminum cans and used machinery oil. An annual backhaul program was instated for electrical equipment and old machinery (ATV, snow-machines and used cars). The solid waste program is operated through the city of White Mountain. The solid waste management practices include publicly restricted access for waste dumping but no enforcement is ordained. Double fencing is installed to control public and to restrict animal access around the dump perimeter as well as draining trenches were constructed to divert runoff water around the dump site. Soil cover material is applied and heavy machinery is used for waste compaction. A burnbox is used for waste reduction and no, uncontrolled open burning of waste material is at the dump site.

The approximately 30 year old above-ground dump is located in an upland area east of the village and north of Fish River. The distance between the dump site and community is approximately 400 m with 300 m to the drinking water source, river system, and berry trails. The dump dimensions are 0.6 km^2 and approximately 4.5 m deep, which creates a 28% slope east/southeast towards lowland area. The dump is observed with shallow soils material composed of silt and gravel underlined by limestone that is encountered at approximately 1.5 m bgs. Standing water and runoff surface water is reported during snowmelt and major rain events. At the dump site a natural drainage channel has formed to the east/southeast side. The community expressed concerns about the dump site's elevated location and the natural drainage channel formed during spring break-up and major rain events resulting into a potential migration of hazardous leachate into the environment.

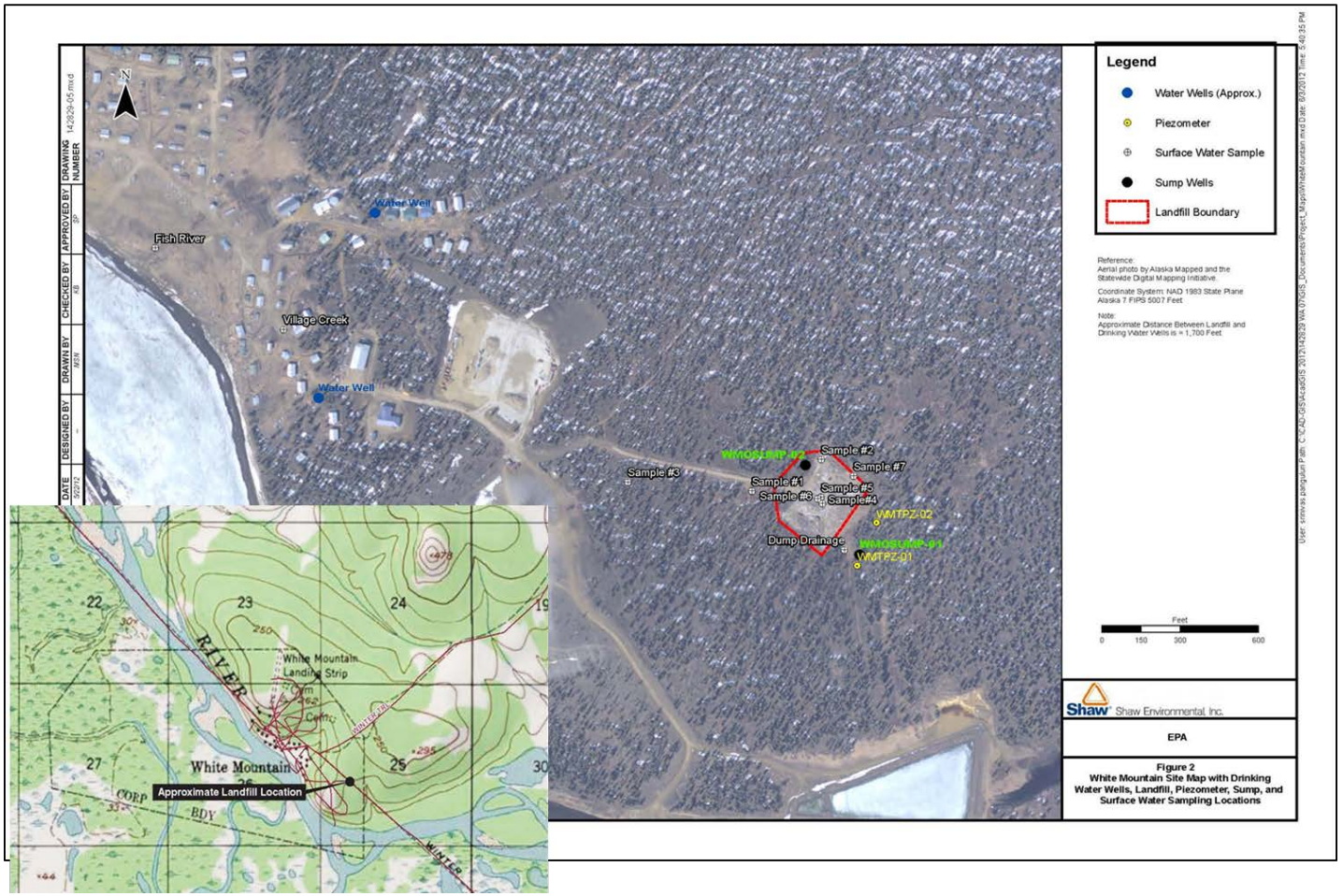
Figure A.v-1: Illustration of scope and extent White Mountain's dump conditions

Table: A.v-1: Sample collection dates and on-site field locations

Date*	Sample Location	GPS	Elevation
a,b	Surface Water at WMOPZ-01	N 64° 40.588' W 163° 23.289'	25m
a,b	Surface Water at Dump Drainage	N 64° 40.600' W 163° 23.329'	25m
a,b	Surface Water at Burnbox	N 64° 40.600' W 163° 23.326'	28m
a,b	Surface Water at Decomposed Waste	N 64° 40.588' W 163° 23.289'	21m
a,b	Village Creek	N 64° 40.588' W 163° 23.289'	16m
a,b	Fish River	N 64° 40.588' W 163° 23.289'	12m
a	Drinking Water	N 64° 40.588' W 163° 23.289'	
a,b	Surface Water at Mid Dump -Mixed Waste	N 64° 40.629' W 163° 23.352'	31m
a,b	Surface Water at Dump Drainage 2	N 64° 40.625' W 163° 23.350'	28m
a,b	Surface Water at Dump Up-gradient	N 64° 40.632' W 163° 23.454'	31m
a	Surface Water at Fenced Area	N 64° 40.651' W 163° 23.330'	37m
a,b	Surface Water at Metal Drums	N 64° 40.653' W 163° 23.358'	36m
a	WMO-Sump 2	N 64° 40.627' W 163° 23.392'	29m
a	WMO-Sump1	N 64° 40.588' W 163° 23.289'	25m

* Data for sample collection a) May 2010, and b) May 2011

White Mountain



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Appendix B: Physiochemical Data

Appendix B-i: Allakaket

Date	Sampling Location	pH	Temperature (^{0}C)	Conductivity (µS/cm)	Alkalinity (ppm)	Total Hardness (ppm)	TOC (ppm)	TSS (mg/L)
Su10	Surface Water Dump-1	7.8	16.9	178.0	240	120		
	Surface Water Dump-2	6.1	11.3	400.0	120	120		
	Surface Water Dump-3	6.2	14.6	1140.0	120	120		
	Drinking Water	7.3		51.0	120	250		
	Slough behind Tribal Office	7.2	17.2	200.0	80	120		
	Koyukuk River	7.8	16.1	290.0	120	120		
	Koyukuk River - Drinking Water Well	7.5	14.7	290.0	80	120		
	Slough Old Dump	7.4	17.6	280.0	120	120		22.7
	Slough before Airport	7.1	19.3	150.0	120	120		
	Slough outlet into Koyukuk River	7.7	16.7	310.0	80	120		
Su11	AEK-Sump01	7.2		449.2	80	120		
Fa11	Surface Water Dump-4	7.8	13.4	580.3	240	425		310.1
	Surface Water Dump-5	8.4	16.6	473.4	180	250		210.0
	Surface Water Dump-1	7.9	15.8	2232.0	240	425		1,600.7
	Surface Water Dump-2	7.4	15.9	1064.0	240	425		1,100.1
	Surface Water Dump-3	7.7	17.4	1642.0	240	425	70.00	1,700.8
	AEKPZ-03	7.2	13.1	484.8	240	425		763.6
	AEK-Sump 02	7.8	14.6	922.0	180	120	148.70	1250.3
	AEKPZ-01	7.4	17.6	899.0	240	240	167.45	19,090.6
	AEKPZ-02	7.4	17.9	4,390.3	180	120	174.75	29,012.5
	Koyukuk River	7.9	15.2	444.0	120	250		22.5
	Slough outlet into Koyukuk River	7.7	17.3	377.1	80	250		2.7

Appendix B-ii: Eek

Date	Sampling Location	pH	Temperature (^{0}C)	Conductivity (µS/cm)	Resistivity (mV)	Alkalinity (ppm)	Total Hardness (ppm)	TOC (ppm)	TSS (mg/L)
Fa09	E_PZ-01	6.5	6.0	644.0					
	E_PZ-02	6.5	3.1	447.1					
Sp10	Dump Pond	7.6	0.4	123.3		80			
	Surface Water at Dump Drainage	7.3	0.2	150.1		80			
	Big Lake	6.8	0.2	119.3		40			
	Drinking Water - Washeteria	7.1		98.4					
	Airport Lake	5.7	0.4	59.9		40			
	Village Pond	6.7	0.6	136.8		40			
	Tundra Pond -Old Runway	6.3	0.7	101.0		40			
Fa10	Eek River	7.5	4.7	136.7		40	120		
	Village Pond	7.6	1.6	150.1		40	120		
	Surface Water at Dump Drainage	7.0	1.1	175.3		80	120		
	Big Lake	7.4	2.1	130.4		40	25		
	Dump Pond	7.5	1.8	147.2		80	120		
	Honeybucket Lagoon	8.2	1.6	175.8		120			
	Airport Lake	7.4	2.7	136.8		40	25		
Sp11	Eek River	7.4	2.9	24.7		40	25		
	Village Pond	6.7	1.8	150.1		40	25		
	Village Creek	6.2	1.2	36.7		40	25		
	Tundra Pond -Old Runway	6.8	1.6	31.3		40	25		
	Surface Water at Dump Drainage	6.4	2.2	85.8		80	25		
	Big Lake	6.4	2.2	115.8		40	25		
	Dump	7.1	4.5	145.0		80	25		73.33
	Honeybucket Lagoon	8.2	2.8	184.5		40	25		
	Airport Lake	7.4	1.6	140.0		40	25		
Fa 11	Eek River	7.0	13	71.7	179.9	40	50	7.04	12.12
	Village Pond	6.6	11.3	89.2	176.8	80	50		8.11
	Surface at Dump Drainage	6.8	10.1	567.4	27.8	240	250	13.12	550.00
	Big Lake	6.9	12.9	77.0	69.2	80	50	4.17	137.85
	Dump Pond	7.2	12.0	224.1	79.9	80	50	37.91	144.44
	Honeybucket Lagoon	6.5	12.9	212.5		80	25		514.29
	Airport Lake	7.7	13.9	170.6	74	20	25	4.45	6.67
	E_PZ-04	7.4		1,090.0		120	180	28.00	581.25
	E_PZ-03	6.8		400.0		40	25	12.99	5,189.09
	E_PZ-02	10.3		2,300.0		80	50		1,632.00
	E_PZ-03	6.9		710.0	0.36				2,433.00

Appendix B-iii: Ekwok

Date	Sampling Location	pH	Temperature (^{0}C)	Conductivity (µS/cm)	Resistivity (mV)	Alkalinity (ppm)	Total Hardness (ppm)	TOC (ppm)	TSS (mg/L)
Sp10	Surface Water at Health Clinic	6.8	1.9			20			
	Klutuk Creek	6.2	2.9			20			
	Surface Water at EKW_PZ-01	5.8	9.3			20			
	Surface Water at EKW_PZ-02	6.2	3.5			20			
	Surface Water at EKW_PZ-03	7.2	2.2			20			
	Surface Water at Gravel Pit	6.9	6.9			20			
	Surface Water Dump-1	6.4	5.2			20			
	Home-Drinking Water Well	7.2				13.1			
	EKWPZ-02					13.2			240.00
Fa10	Klutuk Creek	6.2	4.7			20	25		
	Surface Water at Health Clinic	6.3	6.6	110.2		20	25		
	Surface Water at Gravel Pit/Homes	6.9	8.7	118.9		20	25		
	Surface Water at Gravel Pit	7.2	5.8	228.6		20	25		
	Nushagak River	7.3	5.3	114.6		20	25		
	Sewage Lagoon	8.4	9.2			180	25		
	EKWPZ-03								
	EKWPZ-02								
	EKWPZ-02								
Sp11	Surface Water at EKWPZ-03	7.4	6.8	507		20	25		210.62
	Surface Water at EKWPZ-02	6.3	3.5	435		20	25		150.00
	Surface Water at EKWPZ-01	6.2	6.0	498		20	25		130.51
	EKWPZ-03	7.5	4.8	179		20	25		
	EKWPZ-01	6.2	6.0	498		20	25		530.33
	EKWPZ-02	6.3	3.5	435		20	25		620.22
	Surface Water Dump-1	6.7	11	171		20	25	42.40	
	Surface Water Dump-2	7.2	12.9	282.4		40	50		670.27
	Klutuk Creek	7.6	3.4	18.6		20	25		7.50
	Nushagak River	7.8	1.1	36.5		20	25		5.10
	Surface Water at Health Clinic	7.5	9.2	227.0		20	25		
	Sewage Lagoon	7.4	0.6	810.0		180	25		
	ICAP Office-Well Water	6.7	10.4	145.0					
Fa11	EKWPZ-03	7.5	8.9	569		20	25	60.95	958.89
	EKWPZ-02	6.3	9.3	435		20	25		11,616.00
	Surface Water Dump -2	7.0	19.5	1220.0	9.8	180	120		4,247.00
	Surface Water Dump -3	7.7	19.5	940.2	327.0	80	120	22.44	3,184.44
	Surface Water at Gravel Pit	7.0	12.4	37.5	18.3	40	25		30.33
	Nushagak River	7.4	11.1	61.6	13.3	40	50	3.48	4.49
	Surface Water at Health Clinic	7.0	11.3	14.6	11.5			4.01	
	Sewage Lagoon	7.8	11.4		810.9	180	25		300.00
	Home-Drinking Water Well	7.0		122	9.8				

Appendix B-iv: Fort Yukon

Date	Sampling Location	pH	Temperature ^{0}C	Conductivity mS/cm	Alkalinity ppm	Total Hardness ppm	TOC (ppm)	TSS (mg/L)
Su10	Surface Water Old Lagoon	8.4	12.9	178.0	180	60		
	Drainage-Old Lagoon	6.8	9.4	278.0	240	60		
	Porcupine River	7.9	18.9	19.0	80	120		
	Hospital Lake -Slough	6.8	16.8	42.0	180	120		5.71
	Yukon River	7.9	17.7	19.0	120	120		159.52
	Hospital Lake	8.6	21.3	22.0	80	120		42.86
	Drainage-New Sewage Lagoon	8.4	23.3	128.0	240	425		
	FYPZ-04				399			676.00
	FY-Sump 01				318			2,333.00
Sp11	Drainage-New Sewage Lagoon	8.1	16.9	526.7	180	250		90.52
	Hospital Lake	8.3	12.8	195.4	120	120		26.67
	Yukon River	8.4	13	176.2	80	120	5.62	171.43
	Hospital Lake -Slough	8.4	14.2	178.7	80	120		
	Surface Water Old Lagoon	8.6	21.5	740.0	240	250		50.00
	Surface Water at FYPZ-03	7.2	15.5	1,071.0	40	120		1,400.29
	FYPZ-01	7.8	14.0	3,063.0	240	425	36.38	2,920.00
	Surface Water at FYPZ-02	8.4	5.6	748.9	240			1,776.19
	Surface Water at FYPZ-01	7.7	5.2	1,855.0	240			4,962.00
	Drainage-Old Sewage Lagoon	8.6	21.5	740.0	240	250	13.87	100.00
Fa11	Drainage-Old Sewage Lagoon	8.1	16.9	526.7	180	250		95.00
	Hospital Lake	7.8	16.0	214.6	40	120	8.79	50.00
	Yukon River	8.6	15.3	236.2	80	120		70.00
	Surface Water at FYPZ-01	7.9	14.2	1,429.0	240	250	95.38	429.00
	Surface Water at FYPZ-02	8.6	5.6	1,990.0	240	425		186.05
	FY-Sump2	7.9	7.1	1,812.0	240	425		12.00
	FYPZ-01	6.7		1,363.0	240	250	111.60	6,578.18
	FYPZ-02	7.2		1,749.0	240	250	56.48	5,193.00
	FYPZ-03	7.5		1,237.0	120	180	42.40	3,065.00
	FYPZ-04	7.8		688.0	240	425		1,103.00
	FY-Sump1	8.0	9.9	1,980.0			30.91	1,226.00
	FYSump2	8.2	8.0	1,890.0			27.08	900.00
	FYPZ-02	7.1		2,150.0				16,061.2
	FYPZ-03	7.4		1,480.0				
	FYPZ-04	8.2	8.0	1,890.0				

Appendix B-v: White Mountain

Date	Sampling Location	pH	Temperature (^{0}C)	Conductivity (µS/cm)	Alkalinity (ppm)	Total Hardness (ppm)	TOC (ppm)	TSS (mg/L)
Sp10	Surface Water at WMOPZ-01	6.7	3.2	580	80	120		
	Surface Water at Dump Drainage	7.9	6.0	574	80	120		
	Surface Water at Burnbox	7.3	4.7	1350	80	120		
	Surface Water at Dump Drainage 2	8.4	4.2	1920	240	250		
	Surface Water at Mid Dump -Mixed Waste	7.3	9.5	1350	120	120		
	Surface water at Metal Drums	7.6	10.1	2200	120	120		
	Village Creek	7.8	5.6	80.5	40	50		
	Fish River	7.8	2.3	65.2	40	50		
	Drinking Water	7.2	RT					
Sp11	Standing water at WMOPZ-01	8.7	11.5	245.3	40	50		
	Dump Drainage 2	7.9	20.7	538.1	240	425		208.51
	Surface Water at Burnbox	7.8	21.6	623	240	425		1,700.27
	Surface Water at Dump Drainage	7.7	14.1	878	240	425	45.18	710.11
	Surface Water at Dump Upgradient	8.2	12.4	143.9	40	50		10.00
	Surface Water at Mid Dump -Mixed Waste	8.1	6.2	175.1	40	120		309.30
	Surface Water at Metal Drums	8.2	19.6	200.2	240	425		185.11
	WMO-Sump 2	8.4	1.5	72.9	40	50	56.25	130.33
	WMO-Sump1	8.4	3.7	198.9	40	50		270.03
	Fish River	8.1	7.8	69.1	40	50	4.25	10.00
	Village Creek	8.1	13.4	136.5	40	50		8.57

Appendix B-vi: Sampling Location Summary and Physiochemical Data

	LOCATIONS								
	Allakaket Permafrost Region			Eek Discontinuous Permafrost Region			Ekwok Tundra Ground Region		
Parameters	Subsurface Water	Surface Water	Control	Subsurface Water	Surface Water	Control	Subsurface Water	Surface Water	Control
Metal	5	9	8	6	22	18	11	13	18
Anion	5	7	7	4	17	13	8	11	12
Microbe	4	6	8	2	26	19	3	16	13
TOC	5	4	1	2	2	2	1	1	1
TSS	5	5	3	6	4	5	4	6	4

	Fort Yukon Permafrost Region			White Mountain Bedrock Region		
Parameters	Subsurface Water	Surface Water	Control	Subsurface Water	Surface Water	Control
Metal	13	8	11	2	12	6
Anion	18	7	8	2	11	2
Microbe	2	13	11	1	11	5
TOC	4	4	4	1	1	1
TSS	10	10	5	0	6	4

	LOCATIONS										
	Allakaket Permafrost Region		Eek Discontinuous Permafrost Region		Ekwok Tundra Ground Region		Fort Yukon Permafrost Region		White Mountain Bedrock Region		
Parameters	Impacted Soils	Control	Impacted Soils	Control	Impacted Soils	Control	Impacted Soils	Control	Impacted Soils	Control	Total
Metal	3	2	6	3	3	3	3	2	3	2	30
Microbe	8	3	15	6	13	5	13	5	8	4	80
Soil Moisture Content	2	1	4	1	3	1	3	1	4	1	21

Appendix C: Soil, Surface and Subsurface Water Inorganic Analysis Data

Appendix C-i: ICP-MS Metal Analysis Data for Allakaket

Table 1: Summer 2010 Total (T) and Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D-1 (T)	D-1 (D)	D-2 (T)	D-2 (D)	D-3 (T)	D-3 (D)	T. O. (T)	K. R. (T)	D.W.W (T)	A. (T)	K. R. (T)	O. D (T)
Be	0.3	0.29	0.29	0.29	<LOD	0.58	<LOD	0.35	0.29	0.31	0.30	0.29	0.34
Na	26.0	31085.2	27067.8	25797.9	29288.0	213208.0	216151.8	2532.7	7180.4	805.0	2568.3	669.8	2471.4
Mg	41.2	13917.5	11053.6	10935.1	11459.1	66575.9	75891.2	19825.5	16127.5	6347.2	19097.8	11341.3	19760.9
Al	0.4	101.7	24.3	123.1	17.6	1526.5	19.9	595.916	1.3	21.5	110.3	151.5	317.2
K	37.0	196.5	852.2	998.6	848.7	20267.0	24528.6	412.4	2485.7	308.6	1679.7	1281.1	432.0
Ca	16.4	29830.5	43809.8	43300.3	36123.2	317172.1	300434.5	48702.0	72492.6	38187.9	46094.0	65751.6	54039.3
V	0.6	0.7	0.6	0.9	<LOD	7.8	<LOD	0.8	0.6	0.6	0.6	0.6	1.1
Cr	0.1	0.4	0.4	0.4	<LOD	1.0	<LOD	0.3	<LOD	0.2	0.2	<LOD	0.3
Mn	0.2	19.5	2065.5	2633.9	2299.8	6437.1	6135.9	179.5	3.3	651.6	79.3	272.2	290.0
Fe	11.5	45.1	868.7	2872.3	933.8	36808.3	31632.7	830.0	<LOD	2139.6	324.6	853.7	1314.9
Co	0.3	0.8	4.5	6.7	<LOD	23.7	18.9	2.1	0.3	1.4	0.9	1.4	3.3
Ni	0.4	13.2	7.9	8.8	<LOD	52.1	18.8	11.6	9.1	7.9	9.1	10.0	14.5
Cu	0.3	15.0	1.3	6.7	<LOD	21.3	<LOD	4.7	430.2	0.8	2.5	<LOD	6.3
Zn	0.5	5.6	22.9	180.6	43.4	22.6	13.9	43.5	26.5	9.4	20.3	7.8	67.4
As	0.2	2.3	4.1	5.1	<LOD	9.5	1.6	1.5	0.6	2.5	1.0	2.7	1.7
Se	0.5	<LOD	<LOD	0.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.1	2.3	0.7	0.4	<LOD	0.9	2.2	0.4	0.2	0.4	0.4	0.5	0.4
Ag	0.1	0.1	0.1	0.1	1.4	0.2	1.5	0.1	0.1	0.1	0.1	<LOD	0.1
Cd	0.1	0.1	0.4	0.4	<LOD	0.7	<LOD	0.4	<LOD	<LOD	0.2	<LOD	0.5
Sb	0.3	2.1	0.8	0.9	<LOD	1.4	<LOD	0.6	0.4	0.5	0.5	0.5	0.6
Ba	0.2	29.0	44.1	72.6	45.4	118.5	154.9	26.2	112.5	35.1	20.0	20.0	30.3
Tl	0.8	<LOD	<LOD	0.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.3	<LOD	14.6	16.8	<LOD	8.8	<LOD	1.7	1.6	2.1	0.4	<LOD	4.4
Th	0.6	<LOD	<LOD	0.5	<LOD	1.0	<LOD	0.7	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.9	2.2	<LOD	0.3	<LOD	1.2	<LOD	1.7	<LOD	<LOD	1.6	<LOD	1.8

D. - Surface Water at the Dump Site
D.W.W. - Slough at Koyukuk River near Drinking Water Well
T.O. - Slough at the Tribal Office
A. - Slough at the Airport
K.R. - Koyukuk River
O.D. - Surface Water at the Old Dump Site

Table 2: Fall 2010 Total (T) and Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D-1 (T)	D-1 (D)	D-2 (T)	D-2 (D)	D-3 (T)	D-3 (D)	D-4 (T)	K.R. (T)	K.R. (D)	D.W.W. (T)	D.W.W. (D)
Be	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Na	128.07	67196.5	67180.2	374457.5	386331.4	248104.9	12127.2	14343.9	3638.3	3576.3	3556.9	3510.0
Mg	30.13	38144.9	38376.9	69625.7	69173.2	62688.1	24275.9	29313.6	25551.4	26672.7	23374.4	23689.4
Al	1.22	29.7	<LOD	178.3	65.2	76.1	<LOD	17.9	188.6	57.9	44.1	16.8
Si	167.06	13439.3	12511.4	3787.6	3031.6	<LOD	4337.9	5755.4	2141.3	1941.2	1952.8	1901.1
K	22.59	10559.0	10364.4	147915.8	139597.0	84529.3	4942.7	6133.3	529.1	491.3	1000.6	970.4
Ca	27.61	265416.8	274389.5	126748.2	116619.9	259127.7	124468.4	151467.2	58582.6	57250.9	61520.4	61734.2
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mn	0.36	3578.4	3523.4	1251.9	1178.9	2418.3	297.8	617.7	54.8	26.9	45.5	23.0
Fe	52.48	13765.7	1109.6	4686.2	974.6	5157.8	<LOD	<LOD	429.2	<LOD	72.0	<LOD
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	2.04	67.4	65.2	24.9	23.1	51.2	<LOD	23.4	15.3	14.2	12.7	13.0
Cu	1.85	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	2.0	2.4	<LOD	<LOD
Zn	1.26	2447.2	1118.2	185.5	43.0	126.6	22.2	51.8	67.8	6.4	5.5	5.9
As	0.37	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	15.4	15.3	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	129.5	102.0	138.8	111.9	118.1	50.9	63.1	25.4	24.6	26.8	26.6
Tl	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.9	1.9	1.6	1.7

D. - Surface Water at the Dump Site
D.W.W. - Slough at Koyukuk River near Drinking Water Well
T.O. - Slough at the Tribal Office
A. - Slough at the Airport
K.R. - Koyukuk River
O.D. - Surface Water at the Old Dump Site

Table 3: Fall 2010 Total (T) and Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	AKPZ_01 (T)	AKPZ_01 (T)	AKPZ_02 (T)	AKPZ_03 (T)	AKPZ_03 (D)	AK-Sump-02 (T)	AK-Sump-02 (D)	AK-Sump-01 (D)
Be	0.01	3.82	3.61	4.41	2.17	<LOD	<LOD	<LOD	<LOD
Na	128.07	71645.35	20074.99	55687.54	9957.41	16153.4	124046.75	139455.9	14859.1
Mg	30.13	19531.16	85046.89	30484.23	52650.04	41868.6	29527.53	33111.4	44460.2
Al	1.22	165.94	44156.48	32828.21	28499.56	<LOD	43.52	19.2	22.5
Si	167.06	6654.41	32778.48	21997.05	33193.59	2696.6	5700.76	5357.5	1469.4
K	22.59	8302.98	1031.61	265.64	1199.47	7441.1	6545.68	7165.6	333.6
Ca	27.61	82793.84	329397.58	203982.94	286858.71	127680.2	125315.41	133383.0	135025.5
V	1.80	<LOD	82.63	25.22	50.41	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	134.18	67.26	69.15	4.0	<LOD	<LOD	1.1
Mn	0.36	1715.01	2351.01	2787.10	4898.39	1761.2	1778.51	1945.4	450.2
Fe	52.48	3235.71	37845.92	113452.99	49729.81	<LOD	5007.01	2720.9	1915.7
Co	0.93	<LOD	52.11	44.49	55.79	<LOD	<LOD	<LOD	1.7
Ni	2.04	<LOD	323.24	152.75	143.18	30.2	<LOD	21.8	40.6
Cu	1.85	<LOD	129.06	175.69	281.82	<LOD	<LOD	<LOD	<LOD
Zn	1.26	112.95	1439.76	6374.14	1353.60	<LOD	<LOD	<LOD	9.3
As	0.37	8.23	3.94	<LOD	5.57	<LOD	6.79	<LOD	0.7
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	4.3
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	53.48	283.87	1189.85	1243.83	84.8	66.35	62.8	79.3
Tl	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	28.10	26.77	63.21	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	6.47	21.58	6.29	<LOD	<LOD	<LOD	<LOD	7.8

AKPZ - Subsurface Water Well Samples

AK-Sump - Recharged Subsurface Water obtained from Soil Pits

Table 4: Summer 2010 Anion Metal Analysis (ppm)

Analyte	LOD	D-1	D-2	D-3	T. O.	K. R.	D.W.W	A.	K. R.	S.O. D
F^-	0.03	0.15	0.61	0.08	0.05	0.05	1.52	0.05	0.08	<LOD
Cl^-	0.1	3.5	51.8	278.4	<LOD	<LOD	18.2	<LOD	<LOD	<LOD
NO_2^-	0.08	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.2	<LOD	0.4	<LOD	110.2	109.3	3.9	113.2	<LOD	<LOD
Br^-	0.2	<LOD	<LOD	3.0	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.2	<LOD	<LOD	<LOD	0.5	0.6	<LOD	0.4	<LOD	<LOD
PO_4^{-3}	0.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Surface Water at the Dump Site
D.W.W. - Slough at Koyukuk River near Drinking Water Well
T.O. - Slough at the Tribal Office
A. - Slough at the Airport
K.R. - Koyukuk River
S. O.D. - Surface Water at the Old Dump Site

Table 5: Fall 2011 Anion Metal Analysis (ppm)

Analyte	LOD	D-1	D-2	D-3	D-4	K.R.	AKPZ_01	AKPZ_02	AKPZ_03	AK_Sump-02
F^-	0.03	0.65	129.54	0.04	15.97	13.58	0.13	0.40	0.12	2.27
Cl^-	0.1	29.65	2655.71	5.17	157.75	0.32	10.18	19.70	6.07	109.79
NO_2^-	0.08	<LOD	381.58	<LOD	<LOD	12.30	<LOD	11.52	<LOD	<LOD
SO_4^{-2}	0.2	147.26	746.51	3.05	433.56	164.57	246.30	65.08	6.94	8.64
Br^-	0.2	<LOD	3.32	<LOD	1.35	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.21	<LOD	<LOD
PO_4^{-3}	0.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Surface Water at the Dump Site
K.R. - Koyukuk River
AKPZ - Subsurface Water Samples
AK_Sump - Recharged Subsurface Water obtained from Soil Pits

Appendix C- ii: ICP-MS Metal Analysis Data for Eek

Table 1: Fall 2009- Spring 2010 Total (T) Metal Analysis (ppb)

Analyte	LOD	D09	B.L.09	D.D.09	E.R.09	T.P.09	A.L. 09	H.L. 09	D10	V.P.10	B.L.10	D.D.10	A.L.10	O.A.L.10
Be	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.4	0.4	0.4	0.4	0.5	0.5
Na	128.07	6012.5	250180.5	2657.9	23022.4	2699.5	2683.1	27004.1	10923.2	5317.8	5838.3	12261.3	2617.8	1254.6
Mg	30.13	3926.9	35536.1	585.8	3806.4	658.2	627.4	3658.4	677.8	1278.5	4412.9	1119.2	228.0	545.2
Al	1.22	908.0	96.7	98.6	106.1	68.9	109.3	84.3	43.9	69.6	2.3	38.8	41.0	73.5
Si	167.06	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
K	22.59	961.8	9983.3	469.7	9230.3	163.1	468.6	13159.6	7368.2	7089.3	1171.8	8484.5	1933.3	1798.6
Ca	27.61	18401.5	24695.4	991.4	22100.4	1136.9	1020.5	23157.0	4075.8	4714.0	14382.1	6593.3	477.4	948.5
V	1.80	3.8	2.8	0.4	0.4	0.4	0.4	0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	1.1	0.4	<LOD	<LOD	<LOD	<LOD	<LOD	0.3	0.7	<LOD	0.5	<LOD	<LOD
Mn	0.36	146.2	293.0	14.2	50.1	40.6	10.5	102.9	221.4	441.9	99.3	249.1	112.8	94.4
Fe	52.48	4008.6	2604.1	347.1	580.8	391.1	334.9	2295.1	1167.8	3699.2	41.2	4253.5	414.4	415.5
Co	0.93	1.17	0.67	<LOD	<LOD	<LOD	<LOD	<LOD	0.4	1.6	<LOD	0.6	0.5	0.5
Ni	2.04	6.5	5.4	1.1	4.6	0.7	1.2	5.0	1.5	2.1	2.1	2.9	<LOD	<LOD
Cu	1.85	5.3	4.0	2.8	2.6	<LOD	3.4	<LOD	7.1	7.5	292.3	12.6	1.3	1.3
Zn	1.26	22.2	8.4	6.6	31.2	11.2	3.8	10.6	40.9	51.1	5290.0	146.1	8.6	6.8
As	0.37	3.6	2.2	0.9	0.8	<LOD	0.9	1.2	<LOD	5.8	<LOD	0.8	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	0.3	0.2	<LOD	0.4	<LOD	<LOD	0.4	0.4	0.3	<LOD	0.7	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.3	0.2	1.1	0.4	0.1	0.1
Sb	1.72	0.5	<LOD	<LOD	0.4	<LOD	<LOD	0.3	1.0	0.5	0.5	1.0	0.4	<LOD
Ba	1.05	39.3	43.9	4.3	29.9	1.8	4.0	21.9	13.0	10.8	27.7	23.9	2.8	6.0
Tl	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	1.8	<LOD	<LOD	0.7	<LOD	<LOD	<LOD	0.7	2.2	15.7	3.8	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump
H.L. - Honeybucket Lagoon
D.D. - Dump Drainage
A.R. - Airport Lake
T.P. - Tundra Pond
E.R. - Eek River
B.L. - Big Lake
O.A.L. - Old Airport Lake

Table 2: Fall 2010 Total (T) and Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	E.R (T)	D.D (T)	B.L. (T)	D. (T)	A.L. (T)	S.L. (T)	E.R. (D)	A.L. (D)	D. (D)	D.D. (D)	B.L. (D)
Be	1.40	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Na	53.61	3771.5	24510.4	8598.4	24066.2	205.0	21433.2	3721.8	2235.9	18717.2	21430.6	9086.9
Mg	57.83	3448.6	3601.3	1588.0	3683.9	1265.1	3963.3	3352.1	680.3	2864.8	3102.0	1630.3
Al	0.39	160.2	65.5	53.1	28.8	265.4	864.3	13.0	91.5	11.7	6.7	40.0
K	51.99	579.2	11935.0	3037.3	10695.2	329.8	13794.7	554.3	445.6	8943.3	10081.5	3076.5
Ca	46.94	10830.9	16899.0	5782.8	17123.6	1366.9	19832.8	10446.4	823.0	14593.0	14445.1	5610.4
V	0.12	1.1	1.2	1.0	1.2	1.7	5.7	0.6	2.2	1.2	1.2	0.8
Cr	0.69	<LOD	<LOD	28.7	18.1	1.2	<LOD	34.2	250.0	30.5	36.6	34.7
Mn	0.43	109.5	211.3	24.8	51.0	362.8	324.8	94.7	48.6	19.5	95.5	11.9
Fe	53.68	1967.5	7050.8	1776.6	2383.8	2174.6	33280.4	952.6	1591.1	1005.1	1108.7	1464.1
Co	0.65	<LOD	<LOD	<LOD	<LOD	1.0	<LOD	<LOD	4.6	<LOD	<LOD	<LOD
Ni	1.21	1.5	<LOD	20.2	<LOD	1.6	<LOD	21.4	135.8	15.8	19.3	21.8
Cu	1.54	<LOD	<LOD	2.3	<LOD	4.4	16.4	<LOD	4.2	<LOD	<LOD	1.8
Zn	0.51	2.5	34.8	49.2	155.2	25.9	141.0	24.3	111.3	82.9	27.0	21.5
As	0.20	1.0	<LOD	1.2	<LOD	1.5	6.2	0.6	0.9	<LOD	<LOD	1.1
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	1.91	<LOD	<LOD	3.0	<LOD	<LOD	<LOD	4.2	33.7	<LOD	<LOD	4.4
Ag	1.79	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.41	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.3	<LOD	<LOD	<LOD
Sb	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.29	<LOD	<LOD	0.2	<LOD	0.9	11.6	<LOD	<LOD	<LOD	<LOD	<LOD
Th	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	1.43	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D. - Ponded Dump
V.P. - Village Pond
B.L. - Big Lake
D.D. - Dump Drainage
A.L. - Airport Lake
D.W. - Drinking Water from Washeterria
O.A.L. - Old Airport Lake
S.D.S - Secondary Drinking Water Source (Ice-Meltwater)
E.R. - Eek River
S.L. - Sewage Lagoon

Table 3: Spring 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	D.	D.D.	V.C.	S.L.	B.L.	O.A.L.	E.R.	A.L.	V.P.
Be	0.01	2.43	2.44	0.25	0.25	2.44	0.25	0.26	0.25	2.43
Na	128.07	18375.08	10182.30	3383.71	7900.32	1971.12	1930.97	1888.31	820.07	7596.57
Mg	30.13	3243.91	662.16	615.80	893.70	<LOD	744.39	1011.75	186.93	1598.35
Al	1.22	127.19	74.79	83.86	107.19	69.05	59.58	171.72	39.66	168.00
Si	167.06	<LOD	<LOD	525.74	339.71	<LOD	874.86	1843.67	<LOD	<LOD
K	22.59	11603.81	6708.14	2213.74	6769.85	977.49	1646.37	758.83	826.19	7169.61
Ca	27.61	15398.03	3961.18	1250.41	3199.20	1298.93	1210.10	2592.54	344.68	6444.00
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mn	0.36	241.74	131.99	132.64	119.74	89.41	82.26	129.52	68.80	657.41
Fe	52.48	3126.08	4092.16	2194.05	2461.05	<LOD	1458.22	1464.73	248.22	8054.78
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	2.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cu	1.85	29.75	<LOD	3.04	7.24	<LOD	<LOD	2.93	<LOD	<LOD
Zn	1.26	413.62	67.73	14.64	26.27	28.60	7.00	8.89	12.53	127.25
As	1.85	<LOD	<LOD	2.63	3.46	<LOD	<LOD	<LOD	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	22.13	14.04	5.29	8.10	<LOD	5.38	11.82	2.57	18.40
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump
V.P. - Village Pond
B.L. - Big Lake
D.D. - Dump Drainage
A.L. - Airport Lake
D.W. - Drinking Water from Washeterria
O.A.L. - Old Airport Lake
S.D.S - Secondary Drinking Water Source (Ice-Meltwater)
E.R. - Eek River
S.L. - Sewage Lagoon

Table 4: Spring 2011: Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D.	D.D.	V.C.	S.L.	B.L.	O.A.L.	E.R.	A.L.	V.P.
Be	0.01	0.25	0.25	0.25	0.24	0.24	0.25	0.25	0.25	0.25
Na	128.07	9001.58	6300.99	3430.43	8264.51	1045.77	1909.18	1875.34	812.57	4762.24
Mg	30.13	1659.42	536.46	604.92	850.99	151.37	737.78	969.78	161.72	1117.03
Al	1.22	28.32	20.74	49.99	30.41	8.62	41.55	25.81	19.84	55.37
Si	167.06	326.04	200.62	468.80	283.88	<LOD	875.97	1764.00	<LOD	818.76
K	22.59	5633.75	4184.02	2213.33	6951.45	556.05	1631.40	746.58	823.77	4616.27
Ca	27.61	7787.56	2677.34	1268.51	2922.38	709.25	1238.27	2721.40	315.68	4282.74
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mn	0.36	112.56	81.09	130.28	102.45	45.56	81.66	121.41	65.18	416.96
Fe	52.48	932.25	1817.77	1501.41	1657.61	140.91	1066.01	615.26	160.05	3606.31
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.76
Ni	2.04	2.66	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	2.36
Cu	1.85	10.72	4.67	10.54	2.96	2.18	<LOD	<LOD	<LOD	6.55
Zn	1.26	134.25	17.67	23.90	11.45	6.62	3.80	2.56	5.46	59.53
As	1.85	<LOD	<LOD	<LOD	2.06	<LOD	<LOD	<LOD	<LOD	8.01
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	1.03	0.64	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	7.77	6.23	4.08	4.36	1.92	4.26	8.93	1.96	8.19
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump
V.P. - Village Pond
B.L. - Big Lake
D.D. - Dump Drainage
A.L. - Airport Lake
D.W. - Drinking Water from Washeterria
O.A.L. - Old Airport Lake
S.D.S - Secondary Drinking Water Source (Ice-Meltwater)
E.R. - Eek River
S.L. - Sewage Lagoon

Table 5: Fall 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	B.L.	E.R.	D.	V.P.	D.D.	A.L.	S.L.	S.D.S.	EPZ-01	EPZ-02	EPZ-03	EPZ-03	EPZ-02	EPZ-01
Be	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.11
Na	128.07	8829.9	3350.1	38615.6	7401.9	45915.7	2137.0	23160.4	590.8	90847.66	2806.41	109530.10	81545.57	11710.12	31721.05
Mg	30.13	1634.7	2672.4	5479.2	2200.3	10946.9	546.0	2838.2	<LOD	25090.96	502.38	<LOD	25513.73	1445.02	9012.84
Al	1.22	54.4	204.0	92.9	223.2	91.7	110.6	1174.7	14.7	409.51	2798.35	1365.95	488.31	615.58	12168.97
Si	167.06	442.2	4884.1	<LOD	2183.0	3745.7	<LOD	1496.5	<LOD	5669.35	3940.76	<LOD	<LOD	2450.16	16450.02
K	22.59	2906.9	440.0	16032.7	1351.3	16126.7	426.2	10629.1	<LOD	12093.29	<LOD	<LOD	10401.37	406.35	2616.25
Ca	27.61	5161.2	8672.5	27570.3	9727.5	55662.7	818.6	15707.0	50.4	43012.60	5577.16	1652.51	36268.39	10871.47	25267.58
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	94.50
Cr	0.29	<LOD	0.8	<LOD	1.0	5.2	0.4	1.5	<LOD	<LOD	5.70	6.02	<LOD	10.15	38.97
Mn	0.36	49.6	83.9	88.2	328.9	692.3	19.9	330.8	3.3	2915.81	1317.46	1070.05	1047.66	1596.96	4426.69
Fe	52.48	1383.2	1731.6	4760.6	6763.6	96165.0	889.4	6812.9	<LOD	130770.35	85645.23	81018.80	9559.36	215266.37	404956.67
Co	0.93	<LOD	<LOD	<LOD	1.5	<LOD	<LOD	1.1	<LOD	11.32	10.45	<LOD	<LOD	9.72	33.51
Ni	2.04	<LOD	<LOD	<LOD	4.9	<LOD	<LOD	5.9	<LOD	<LOD	<LOD	<LOD	<LOD	25.35	104.04
Cu	1.85	<LOD	<LOD	<LOD	4.4	<LOD	2.3	28.7	<LOD	42.96	<LOD	<LOD	<LOD	<LOD	87.13
Zn	1.26	2.9	1.8	231.4	36.2	1144.2	11.4	102.2	8203.4	297.62	9584.81	1547.20	1776.15	7245.41	1007.75
As	1.85	1.0	0.8	<LOD	11.6	<LOD	0.6	6.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	5.53
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	13.6	19.2	43.7	15.3	174.9	4.3	57.4	<LOD	237.64	56.26	58.62	93.01	43.98	455.57
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	6.3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	29.04
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	7.25	<LOD	<LOD	<LOD

D - Ponded Dump
V.P. - Village Pond
B.L. - Big Lake
D.D. - Dump Drainage
A.L. - Airport Lake
E.R. - Eek River
S.L. - Sewage Lagoon
EPZ - Subsurface Water Samples
S.D.S - Secondary Drinking Water Source (Rain Catchment)

Table 6: Fall 2011: Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	B.L.	E.R	D.	V.P.	D.D.	A.L.	S.D.S.	EPZ-01	EPZ-02	EPZ-03
Be	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Na	128.07	8879.9	3341.8	17098.8	7531.1	48692.3	2092.0	529.6	3034.1	9028.7	607.1
Mg	30.13	1628.8	2651.1	2089.7	2172.3	11703.0	525.5	<LOD	516.2	2379.6	<LOD
Al	1.22	33.9	33.8	<LOD	89.1	<LOD	79.7	2.0	<LOD	<LOD	<LOD
Si	167.06	440.3	4481.4	<LOD	2085.3	3072.6	<LOD	<LOD	343.8	171.4	<LOD
K	22.59	2930.4	418.3	6926.0	1310.1	17588.1	381.3	<LOD	134.8	1225.6	<LOD
Ca	27.61	5028.2	8125.8	12504.8	9389.8	56319.7	679.3	55.9	1334.4	3292.9	297.7
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	0.3	<LOD	<LOD	0.9	6.4	0.3	<LOD	<LOD	<LOD	<LOD
Mn	0.36	18.2	58.9	24.9	264.9	712.4	11.8	2.7	220.7	92.6	90.1
Fe	52.48	914.3	635.0	<LOD	3975.3	43044.6	537.1	<LOD	7778.5	<LOD	<LOD
Co	0.93	<LOD	<LOD	<LOD	1.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	2.04	<LOD	<LOD	<LOD	4.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cu	1.85	<LOD	<LOD	<LOD	3.6	<LOD	2.1	<LOD	<LOD	<LOD	<LOD
Zn	1.26	6.2	3.3	67.2	27.9	424.5	3.3	7357.9	13.3	<LOD	50.2
As	1.85	0.9	<LOD	<LOD	8.2	<LOD	0.5	<LOD	<LOD	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	12.7	15.7	18.6	11.9	98.9	3.3	1.2	7.4	3.8	<LOD
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump
V.P. - Village Pond
B.L. - Big Lake
D.D. - Dump Drainage
A.L. - Airport Lake
E.R. - Eek River
S.L. - Sewage Lagoon
EPZ - Subsurface Water Samples
S.D.S - Secondary Drinking Water Source (Rain Catchment)

Table 7: Spring and Fall 2010 Anion Metal Analysis (ppm)

Analyte	LOD	D. Sp10	D.D. Sp10	B.L. Sp10	A.L. Sp10	V.P. Sp10	S.D.S. Sp10	E.R. Fa10	V.P. Fa10	A.L. Fa10	S.L. Fa10	D. Fa10	D.D. Fa10	B.L. Fa10
F^-	0.03	0.04	0.04	<LOD	0.06	<LOD	<LOD	0.06	0.04	0.04	0.04	0.06	<LOD	0.04
Cl^-	0.17	14.73	15.79	7.69	5.76	3.98	10.10	2.05	9.55	2.59	26.99	26.50	28.76	11.04
NO_2^-	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.40	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.14	8.17	11.71	0.86	8.59	0.52	1.94	9.04	0.83	0.79	1.37	1.94	3.12	1.31
Br^-	0.11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.04	0.25	0.15	<LOD	0.40	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.90	<LOD	<LOD
PO_4^{-3}	0.28	2.28	2.28	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump S.D.S - Secondary Drinking Water Source (Ice-Meltwater) B.L. - Big Lake A.L. - Airport Lake
V.P. - Village Pond D.D. - Dump Drainage E.R. - Eek River S.L. - Sewage Lagoon

Table 8: Spring 2011 Anion Metal Analysis (ppm)

Analyte	LOD	E.R.	S.L.	D.	D.D.	B.L.	A.L.	V.P.	V.C.	O.A.L.
F^-	0.06	0.05	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.03
Cl^-	0.10	1.92	10.62	9.70	7.76	1.50	1.20	4.58	6.19	2.85
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.23	2.55	2.69	8.02	2.87	0.59	0.42	1.21	1.45	0.82
Br^-	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.30	<LOD	1.67	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
PO_4^{-3}	0.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump O.A.L. - Old Airport Lake B.L. - Big Lake A.L. - Airport Lake
V.P. - Village Pond D.D. - Dump Drainage E.R. - Eek River S.L. - Sewage Lagoon
V.C. - Village Creek

Table 9: Fall 2011 Anion Metal Analysis (ppm)

Analyte	LOD	B.L.	E.R.	D.	V.P.	D.D.	A.L.	S.L.	S.D.S	EPZ-01	EPZ-03	EPZ-02	EPZ-03
F^-	0.06	0.06	0.06	0.08	0.05	0.10	0.05	<LOD	<LOD	0.03	0.13	<LOD	0.10
Cl^-	0.10	9.06	1.65	28.01	6.53	32.77	2.03	53.03	1.39	1.44	6.54	1.47	5.22
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.23	0.85	7.30	0.56	0.51	0.93	0.74	2.89	0.71	1.62	1.97	0.79	3.41
Br^-	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.42	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.30	<LOD	<LOD	<LOD	<LOD	0.50	0.02	0.60	<LOD	0.16	0.59	0.22	0.08
PO_4^{-3}	0.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D - Ponded Dump E.R. - Eek River A.L. - Airport Lake
V.P. - Village Pond S.L. - Sewage Lagoon
B.L. - Big Lake EPZ - Subsurface Water Samples
D.D. - Dump Drainage S.D.S - Secondary Drinking Water Source (Rain Catchment)

Appendix C-iii: ICP-MS Metal Analysis Data for Ekwok

Table 1: Spring - Summer 2010 Total (T) Metal Analysis (ppb)

Analyte	LOD	D. #3	K.C.	D. #1	EKPZ_02	D. #2	G.P.	D.	D.S.	EKWPZ_02	EKWPZ_02	EKWPZ_03	EKWPZ_03	EKWPZ_02	EKWPZ_02
Be	0.28	0.4	0.4	0.4	0.6	0.4	0.5	0.5	0.4	<LOD	0.3	0.6	2.6	2.1	0.4
Na	25.96	683.3	1718.3	916.2	1490.8	1015.7	442.5	649.8	3142.6	1939.7	1533.2	2079.9	4483.1	4891.3	4919.0
Mg	41.18	454.0	792.2	685.6	495.9	560.1	361.7	307.1	1921.3	526.7	647.0	657.9	1291.4	953.2	310.6
Al	0.36	130.7	31.6	186.6	3564.4	43.3	689.9	279.1	0.6	4495.6	5433.2	5593.5	98358.8	56571.0	105.9
K	37.03	2803.2	552.1	2451.2	310.3	2137.3	1834.0	850.0	404.0	365.3	427.0	460.1	1344.1	925.6	286.2
Ca	16.38	1985.2	2742.2	1830.3	1697.1	7207.5	1427.0	908.2	5540.6	1958.1	2239.4	2045.6	8254.9	6655.0	1274.3
V	0.57	0.2	<LOD	<LOD	8.8	<LOD	1.8	<LOD	<LOD	6.7	8.6	11.2	48.7	44.2	<LOD
Cr	0.11	0.0	<LOD	<LOD	27.3	<LOD	0.6	<LOD	<LOD	11.2	8.8	16.6	76.0	58.2	1.0
Mn	0.15	62.2	74.3	177.3	386.9	267.6	93.4	39.0	1.6	469.5	604.5	815.9	890.1	708.2	326.8
Fe	11.51	125.5	299.9	295.1	27183.8	141.4	805.3	320.2	39.6	17915.4	9872.4	21267.8	282960.5	97788.3	58557.8
Co	0.30	0.1	<LOD	<LOD	7.4	0.8	0.4	<LOD	<LOD	8.9	10.9	13.4	15.2	11.4	4.9
Ni	0.41	0.1	<LOD	<LOD	102.3	0.6	<LOD	<LOD	<LOD	60.9	20.0	26.9	74.1	68.1	6.4
Cu	0.31	3.0	0.7	2.0	196.5	7.6	2.8	0.9	56.4	44.1	23.4	34.9	124.8	119.6	12.6
Zn	0.54	20.6	5.1	19.5	318.3	24.4	27.4	5.2	3.7	162.7	83.8	185.9	5968.8	3617.0	142.5
As	0.15	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.4	0.9	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.13	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.6	0.7	0.3
Ag	0.14	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.3	0.2	<LOD
Cd	0.07	0.1	<LOD	0.1	0.1	0.1	0.2	<LOD	<LOD	0.1	<LOD	<LOD	0.7	0.4	0.3
Sb	0.34	0.5	<LOD	0.4	0.4	0.5	0.4	<LOD	<LOD	<LOD	<LOD	<LOD	0.5	<LOD	0.4
Ba	0.21	7.2	7.6	6.9	57.1	18.9	13.2	7.4	2.4	78.4	123.0	88.0	338.7	306.3	8.5
Ti	0.84	0.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.25	0.8	<LOD	0.5	4.0	0.5	3.0	<LOD	<LOD	2.6	2.4	4.1	21.3	15.1	0.6
Th	0.61	0.8	0.8	0.8	0.9	0.8	0.8	0.8	0.8	<LOD	<LOD	0.7	3.7	2.0	<LOD
U	0.92	0.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.8	3.4	<LOD

D. #3 - Surface Water at EKWPZ-03
D. #2 - Surface Water at EKWPZ-02
D. #1 - Surface Water at EKWPZ-01
K.C. - Klutuk Creek
D.S. - Drinking Water Source
G.P. - Lagoon at Gravel Pit
D. - Surface Water between old and new Dump Trench
EKWPZ - Subsurface Water Well Samples

Table 2: Fall 2010 Total (T) and Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	S.L. (T)	D.S. (T)	O.D. (T)	G.P. (T)	N.R. (T)	G.L. (T)	K.C. (T)	D.S.-1 (D)	K.C. (D)	O.D. (D)	G.P. (D)
Be	1.40	<LOD	<LOD	<LOD	<LOD	<LOD	5.23	<LOD	<LOD	<LOD	<LOD	<LOD
Na	53.61	102808.39	3259.77	2107.42	2855.99	1829.48	2983.62	1870.41	3362.28	1872.83	1031.94	2223.61
Mg	57.83	5256.30	1976.62	1439.47	947.42	1917.55	1053.25	702.78	2080.68	729.01	977.80	796.22
Al	0.39	657.47	1.88	23.74	64.44	44.87	24.51	10.45	1.17	13.09	28.07	5.32
K	51.99	20063.34	439.59	2213.65	773.24	331.13	660.37	494.75	442.43	599.07	1592.73	599.02
Ca	46.94	15440.04	5654.06	5250.69	4120.29	7834.33	4686.61	2806.13	5598.19	2743.99	3692.41	3618.73
V	0.12	1.88	0.20	2.08	1.16	0.41	0.77	0.17	0.20	0.21	1.16	1.16
Cr	0.69	<LOD	<LOD	8.90	<LOD	<LOD	1.50	<LOD	<LOD	<LOD	<LOD	<LOD
Mn	0.43	244.05	6.11	358.02	18.53	22.19	2.57	4.68	5.65	8.13	240.80	<LOD
Fe	53.68	2850.33	73.43	5093.03	<LOD	490.25	216.47	<LOD	<LOD	83.21	810.76	<LOD
Co	0.65	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	1.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cu	1.54	153.12	2137.95	<LOD	<LOD	<LOD	<LOD	<LOD	314.38	<LOD	<LOD	<LOD
Zn	0.51	85.64	47.39	430.95	72.23	4.14	3.75	4.87	15.20	1.32	<LOD	<LOD
As	0.20	3.15	0.28	2.44	<LOD	0.72	0.92	<LOD	<LOD	<LOD	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	0.50	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	1.91	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	1.79	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.41	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	0.02	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	0.22	13.77	2.84	19.20	8.96	6.88	6.02	6.11	2.68	7.15	13.54	6.13
Ti	0.71	<LOD	<LOD	<LOD	<LOD	<LOD	0.20	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.29	<LOD	1.24	<LOD	<LOD	<LOD	0.19	<LOD	<LOD	<LOD	<LOD	<LOD
Th	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	<LOD	<LOD	<LOD	<LOD	<LOD
U	1.43	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D. #3 - Surface Water at EKW_PZ-03
D. #2 - Surface Water at EKW_PZ-02
D. #1 - Surface Water at EKW_PZ-01
N.R. - Nushagak River
K.C. - Klutuk Creek
D.S. - Drinking Water Source
G.P. - Surface Water from Gravel Pit
D. - Surface Water between old and new Dump Trench
S.L. - Sewage Lagoon
G.L. - Gravel Pit Lagoon

Table 3: Spring 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	D.S.-2	N.R.	EKWPZ_01	EKWPZ_02	EKWPZ_03	D. #1	D. #2	D. #3	D.-1	D.-2	O.D.	K.C.	D.S.-3	S.L.
Be	0.01	0.26	0.26	4.15	2.47	3.23	0.25	0.25	0.25	0.28	0.27	0.25	0.25	0.24	0.36
Na	128.07	1782.00	1455.28	25458.29	1912.28	6225.48	701.59	746.65	1828.21	1024.75	6133.43	805.38	1816.12	3996.44	5107.97
Mg	30.13	465.58	1077.11	748.37	<LOD	<LOD	374.23	539.99	667.38	331.76	2545.83	407.58	859.62	3434.76	1881.11
Al	1.22	170.90	235.31	5004.24	714.41	29607.28	75.49	131.04	199.20	2309.23	363.66	266.36	137.80	3.65	5867.58
Si	167.06	3814.65	3228.77	5633.93	7085.84	12221.92	512.18	598.18	1529.92	1820.34	3212.75	334.57	4243.12	9392.65	7730.05
K	22.59	234.53	679.53	834.25	<LOD	811.60	1265.22	2028.46	4903.19	454.73	4189.30	1619.87	467.44	670.47	2670.39
Ca	27.61	1750.97	3575.02	2681.18	1496.05	1581.66	1035.87	1398.30	2842.94	1121.43	51474.48	950.13	2462.71	10158.50	7685.47
V	1.80	<LOD	<LOD	<LOD	<LOD	27.94	<LOD	<LOD	<LOD	2.59	<LOD	<LOD	<LOD	<LOD	4.73
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.29
Mn	0.36	32.16	57.67	1007.00	206.73	524.65	35.81	56.93	79.69	25.07	1321.27	70.09	43.54	81.54	240.02
Fe	52.48	1182.82	842.68	96715.08	62442.49	50780.91	209.47	242.74	510.48	1462.24	477.87	427.59	289.01	15347.88	8016.93
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	2.78	<LOD	<LOD	<LOD	1.29
Ni	2.04	2.47	<LOD	21.22	22.99	<LOD	<LOD	<LOD	<LOD	<LOD	11.18	<LOD	<LOD	3.50	5.48
Cu	1.85	387.68	<LOD	74.17	71.52	19.84	1.90	<LOD	9.30	2.06	4.48	<LOD	<LOD	43.56	602.39
Zn	1.26	1743.75	9.81	36405.74	728.49	6511.58	20.46	22.93	44.08	22.29	30.29	8.79	7.07	43.36	352.55
As	1.85	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.18
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.56
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	8.44	6.96	57.99	15.18	44.78	3.03	5.21	7.59	19.70	60.76	5.68	5.69	6.53	70.10
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	25.98	<LOD	18.40	<LOD	<LOD	<LOD	<LOD	1.05	1.07	2.24	<LOD	<LOD	1.38	7.53
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	6.37	2.46	3.48	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D. #3 - Surface water at EKWPZ-03
D. #2 - Surface water at EKWPZ-02
K.C. - Klutuk Creek
D. #1 - Surface water at EKWPZ-01
D.S. 2- Drinking Water Source at Health Center
D.S. 3- Drinking Water Source at ICAP Center
S.L. - Sewage Lagoon
N.R. - Nushagak River
D.-1 - Surface Water between old and new Dump Trench
D.-2 - Surface Water at new Dump Trench
EKWPZ - Subsurface Water Well Samples

Table 4: Spring 2011 Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D.S.-2	N.R.	EKWPZ_01	EKWPZ_02	EKWPZ_03	D. #1	D. #2	D. #3	D.-1	D.-2	O.D.	K.C.	D.S.-3	S.L.
Be	0.01	0.25	0.25	1.23	0.24	0.25	0.25	0.25	0.27	0.26	0.26	0.25	0.25	0.25	0.26
Na	128.07	1846.80	1456.69	43794.59	1697.44	4261.68	775.88	770.25	1848.47	1010.19	6228.65	854.97	1829.56	4074.26	5146.62
Mg	30.13	428.07	978.72	<LOD	284.03	<LOD	377.04	493.61	635.08	243.67	2339.06	386.10	895.12	3283.78	1100.94
Al	1.22	20.22	35.48	87.86	5.57	12.35	65.29	98.16	143.30	508.99	88.27	140.72	50.23	5.73	82.03
Si	167.06	4527.11	2516.15	<LOD	3410.58	<LOD	499.61	567.97	1509.80	1107.94	3197.40	291.20	4007.54	8695.44	5787.40
K	22.59	227.72	650.23	718.22	880.25	1126.91	1261.51	1922.85	5045.56	429.68	4026.99	1615.40	460.25	791.06	1989.70
Ca	27.61	1725.29	3095.67	194.82	1100.80	66.70	1007.87	1309.30	2650.56	1117.48	44825.68	929.59	2505.89	10078.23	3765.65
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mn	0.36	28.33	31.65	7.69	40.32	24.01	38.28	42.30	76.79	24.78	1129.41	58.09	35.60	76.28	127.60
Fe	52.48	418.67	267.49	<LOD	566.70	149.06	167.98	199.70	382.26	323.59	204.54	165.97	218.28	12616.59	497.15
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	2.56	<LOD	<LOD	<LOD	<LOD
Ni	2.04	2.38	<LOD	<LOD	4.41	<LOD	<LOD	<LOD	<LOD	<LOD	9.50	<LOD	<LOD	2.50	<LOD
Cu	1.85	306.10	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	8.98	<LOD	3.93	2.23	<LOD	8.50	12.24
Zn	1.26	1534.82	3.57	128.43	80.21	165.41	16.00	16.43	37.03	4.46	111.54	6.85	3.25	13.60	36.53
As	1.85	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.60
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	7.04	4.00	<LOD	3.67	<LOD	2.76	4.05	6.90	9.29	52.46	4.15	4.41	6.70	3.16
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	8.44	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D. #3 - Surface Water at EKWPZ-03
D. #2 - Surface Water at EKWPZ-02
O.D. - Surface Water at Old Dump
D. #1 - Surface water at EKWPZ-01
D.S. 2- Drinking Water Source at Health Center
D.S. 3- Drinking Water Source at ICAP Center
S.L. - Sewage Lagoon
N.R. - Nushagak River
EKWPZ - Subsurface Water Well Samples
K.C. - Klutuk Creek
D.-2 - Surface Water at new Dump Trench
D.-1 - Surface Water between old and new Dump Trench

Table 5: Summer - Fall 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	EKWPZ_01	EKWPZ_02	EKWPZ_03	EKWPZ_03	EKWPZ_02	EKWPZ_03	S.L.	O.D.	N.R.	D.S.	D. #2	G.P.
Be	0.01	4.15	2.47	3.23	1.74	1.09	1.17	<LOD	<LOD	<LOD	<LOD	0.70	<LOD
Na	128.07	25458.29	1912.28	6225.48	1214.66	8181.79	5106.17	73719.61	1348.22	2845.62	6501.23	1817.55	3131.08
Mg	30.13	748.37	<LOD	<LOD	878.47	6005.68	1903.58	6658.44	505.67	2501.89	3955.95	1248.15	803.04
Al	1.22	5004.24	714.41	29607.28	21156.92	95132.59	74482.20	3403.24	1024.91	146.87	22.48	25945.41	18.72
Si	167.06	5633.93	7085.84	12221.92	10412.62	59762.45	50224.75	14840.95	2205.68	4989.15	16485.21	10164.67	7961.01
K	22.59	834.25	<LOD	811.60	390.20	2596.03	1347.12	21319.65	935.61	<LOD	828.60	1502.80	527.26
Ca	27.61	2681.18	1496.05	1581.66	4639.46	15624.69	8470.31	17683.65	1797.21	10912.29	12710.30	3685.88	3444.73
V	1.80	<LOD	<LOD	27.94	2.20	70.19	49.11	<LOD	<LOD	<LOD	<LOD	53.91	<LOD
Cr	0.29	<LOD	<LOD	<LOD	7.82	123.74	37.22	<LOD	<LOD	<LOD	<LOD	9.24	<LOD
Mn	0.36	1007.00	206.73	524.65	721.98	2327.58	1075.71	316.16	92.18	28.88	<LOD	703.60	9.97
Fe	52.48	96715.08	62442.49	50780.91	27680.71	248165.62	178483.56	6743.12	1828.71	720.60	<LOD	12077.25	<LOD
Co	0.93	<LOD	<LOD	<LOD	4.69	54.99	<LOD	<LOD	<LOD	<LOD	<LOD	6.24	<LOD
Ni	2.04	21.22	22.99	<LOD	25.62	1857.20	<LOD	<LOD	<LOD	<LOD	<LOD	3.54	<LOD
Cu	1.85	74.17	71.52	19.84	22.97	166.15	63.90	452.12	<LOD	<LOD	31.99	38.12	<LOD
Zn	1.26	36405.74	728.49	6511.58	3912.69	703.40	12587.05	375.25	<LOD	<LOD	16.81	76.16	<LOD
As	1.85	<LOD	<LOD	<LOD	0.81	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.98	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.51	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	57.99	15.18	44.78	102.67	757.85	220.61	51.80	15.29	11.07	<LOD	181.74	4.42
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	18.40	<LOD	<LOD	3.00	32.29	21.20	<LOD	<LOD	<LOD	<LOD	29.44	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	6.37	2.46	3.48	1.66	7.32	7.82	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D. #2 - Surface Water at EKWPZ-02
D.S. - Drinking Water Source at ICAP Center
S.L. - Sewage Lagoon
EKWPZ - Subsurface Water Well Sample
N.R. - Nushagak River
G.P. - Surface Water from Gravel Pit

Table 6: Summer - Fall 2011 Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D. #2	G.P.	S.L.	O.D.	N.R.
Be	0.01	<LOD	<LOD	<LOD	<LOD	<LOD
Na	128.07	1415.20	3135.47	20585.48	746.38	2012.83
Mg	30.13	80.93	760.79	1100.01	314.04	2041.37
Al	1.22	235.93	3.00	37.77	106.76	26.05
Si	167.06	554.56	7748.53	4855.53	1384.20	4110.65
K	22.59	761.28	479.59	4640.22	917.88	334.80
Ca	27.61	578.74	3359.11	3815.04	1252.18	8455.34
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD
Mn	0.36	64.44	10.24	36.92	20.93	9.94
Fe	52.48	281.69	<LOD	291.52	192.23	273.30
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	2.04	<LOD	<LOD	<LOD	<LOD	<LOD
Cu	1.85	10.46	<LOD	22.00	<LOD	<LOD
Zn	1.26	6.63	<LOD	6.91	2.54	10.94
As	1.85	0.43	<LOD	<LOD	<LOD	0.57
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	3.89	4.68	2.66	4.29	6.59
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	<LOD	<LOD	<LOD	<LOD	<LOD

D. #2 - Surface Water at EKWPZ-02
S.L. - Sewage Lagoon
N.R. - Nushagak River
EKW_PZ - Subsurface Water Well Sample
G.P. - Surface Water from Gravel Pit

Table 7: Spring - Fall 2010 Anion Metal Analysis (ppm)

Analyte	LOD	O.D. Sp10	D. #1 Sp10	EKWPZ_02 Sp10	D. #3 Sp10	D.-2 Sp10	O.D. Fa10	N.R. Fa10	S.L. Fa10	G.P. Fa10
F^-	0.01	<LOD	0.03	<LOD	0.02	<LOD	0.04	0.05	0.09	0.07
Cl^-	0.18	0.28	0.36	0.47	0.25	0.28	2.79	0.40	62.30	1.31
NO_2^-	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.30
SO_4^{-2}	0.03	2.92	1.15	1.60	1.57	9.80	1.18	5.87	8.10	1.36
Br^-	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.15	0.21	0.30	<LOD	0.42	0.15	<LOD	0.51	<LOD	<LOD
PO_4^{-3}	0.29	0.40	<LOD	0.56	<LOD	<LOD	<LOD	<LOD	8.02	<LOD

D. #1 - Surface Water at EKW_PZ-02 D. #3 - Surface Water at EKW_PZ_03 EKW_PZ - Subsurface Water Well Sample
S.L. - Sewage Lagoon D.-2 - Surface Water at new Dump Trench G.P. - Surface Water from Gravel Pit
N.R. - Nushagak River O.D. - Surface Water at Old Dump

Table 8: Spring 11 Anion Metal Analysis (ppm)

Analyte	LOD	EKWPZ_ 01	EKWPZ_ 02	EKWPZ_ 03	D. #1	D. #2	D. #3	D. -1	D. -2	O.D.	K.C.	D.S.-3	N.R.	S.L.	D.S.-2
F^-	0.06	0.06	0.04	0.05	0.01	<LOD	0.02	0.01	0.03	0.01	0.05	0.04	0.05	0.03	0.04
Cl^-	0.10	0.77	1.47	1.20	0.91	1.01	2.39	1.32	8.05	1.40	1.17	1.82	0.94	3.41	1.92
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.23	5.26	1.07	0.83	0.46	0.64	3.78	1.68	68.00	0.65	1.09	1.48	2.37	1.88	1.62
Br^-	0.07	<LOD	<LOD	0.17	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.30	0.55	0.06	<LOD	<LOD	<LOD	0.93	0.12	3.99	<LOD	<LOD	<LOD	0.13	<LOD	<LOD
PO_4^{-3}	0.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

D. #1 - Surface Water at EKW_PZ-02 D. #3 - Surface Water at EKW_PZ_03 EKWPZ - Subsurface Water Well Sample
S.L. - Sewage Lagoon D.-2 - Surface Water at new Dump Trench
N.R. - Nushagak River O.D. - Surface Water at Old Dump

Table 9: Fall 11 Anion Metal Analysis (ppm)

Analyte	LOD	D.-2	G.P.	S.L.	O.D.	N.R.
F^-	0.06	0.04	0.06	0.15	0.03	0.07
Cl^-	0.10	1.13	1.31	56.82	0.52	1.16
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.23	1.36	1.37	4.00	0.52	7.29
Br^-	0.07	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.30	0.44	<LOD	<LOD	<LOD	0.15
PO_4^{-3}	0.31	<LOD	<LOD	13.19	<LOD	<LOD

D. -2 - Surface Water at new Dump Trench G.P. - Surface Water from Gravel Pit
S.L. - Sewage Lagoon O.D. - Surface Water at Old Dump
N.R. - Nushagak River

Appendix C- iv: ICP-MS Metal Analysis Data for Fort Yukon

Table 1: Spring 2010 Total (T) Metal Analysis (ppb)

Analyte	LOD	FYPZ_04	FYPZ_02	FYPZ_01	D. #1	H.L.S.	S.L.	P.R.	H.L.	D.#2	D.#3	Y.R.	FYPZ_01	FYPZ_04	FYPZ_02	FYPZ_01
Be	0.3	0.8	1.3	1.5	3.9	0.3	<LOD	<LOD	<LOD	3.9	3.9	<LOD	<LOD	0.5	1.0	1.2
Na	26.0	181616.1	184746.4	21356.2	298936.9	34564.4	6735.1	3003.3	2765.6	178113.4	287784.3	2569.7	298936.9	181616.1	184746.4	21431.2
Mg	41.2	125383.7	102451.8	115151.7	113015.3	94802.4	18061.8	7177.4	8322.7	87707.1	113693.2	9168.6	142323.7	157066.9	124484.9	155253.7
Al	0.4	3062.2	5263.1	1311.5	126.7	14.2	15.0	41.2	12.3	41.3	494.2	214.9	127.5	3440.8	5829.0	1534.4
K	37.0	36885.2	24611.1	5236.7	49405.0	7664.6	3947.4	690.5	2677.8	52882.9	48106.8	1032.8	55609.4	42639.4	27933.6	5245.8
Ca	16.4	177551.2	136685.1	430527.9	171403.9	162612.5	68926.0	35611.3	36981.2	122977.5	181270.3	34898.3	<LOD	179160.9	131783.7	446653.3
V	0.6	23.7	39.5	20.8	1.3	1.8	1.0	1.0	1.1	1.3	2.2	1.6	<LOD	23.6	39.5	20.8
Cr	0.1	26.1	57.4	13.1	3.9	2.3	0.5	0.5	0.4	2.2	3.4	0.8	<LOD	26.0	57.5	12.8
Mn	0.2	1672.1	1508.6	8932.8	1357.7	8691.7	430.0	26.2	13.7	629.9	1543.8	48.4	1359.4	1816.3	1654.3	10664.7
Fe	11.5	68368.9	36375.2	24985.2	12569.5	1840.0	540.0	229.5	113.9	5454.8	14811.3	463.7	<LOD	76903.7	41747.8	28973.1
Co	0.3	14.5	16.3	30.9	2.4	13.0	1.1	0.6	0.6	3.2	2.7	0.8	2.0	14.2	16.0	30.7
Ni	0.4	111.0	223.9	152.4	33.3	48.1	12.2	6.7	7.2	28.3	36.5	6.7	32.3	132.3	278.1	196.3
Cu	0.3	20.0	25.2	11.6	13.4	8.8	3.8	2.0	1.4	8.1	25.8	3.1	<LOD	19.8	25.0	11.3
Zn	0.5	361.5	414.5	178.7	48.8	5.9	6.1	6.9	2.6	68.9	113.0	7.9	47.0	503.7	564.2	260.0
As	0.6	8.9	12.6	22.2	4.2	6.8	3.5	0.7	2.4	2.4	5.7	1.0	<LOD	7.3	10.7	15.4
Se	0.5	0.6	0.7	1.2	<LOD	3.8	0.5	<LOD	<LOD	<LOD	0.5	0.9	<LOD	<LOD	<LOD	0.9
Mo	0.1	4.6	4.9	1.6	2.6	6.3	2.0	0.7	1.2	2.2	1.8	1.1	2.3	4.4	4.7	1.4
Ag	0.1	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.3	<LOD	<LOD	<LOD	<LOD
Cd	0.1	0.9	1.0	20.0	0.3	0.4	0.2	0.2	0.2	2.8	3.4	0.3	<LOD	<LOD	0.7	19.8
Sb	0.3	1.4	1.8	1.9	3.3	1.6	0.7	0.6	0.7	3.4	3.2	0.7	3.0	1.2	1.6	1.7
Ba	0.2	356.6	747.2	684.8	319.7	384.8	299.3	58.7	69.7	147.6	252.1	58.1	291.6	358.0	721.0	648.5
Ti	0.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.3	13.7	12.4	3.3	5.0	<LOD	<LOD	0.6	<LOD	1.0	17.3	0.6	4.8	13.5	12.2	3.1
Th	0.6	1.4	0.8	4.1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.1	<LOD	3.8
U	0.9	37.8	10.5	3.5	<LOD	15.3	1.2	<LOD	<LOD	<LOD	<LOD	1.2	<LOD	37.7	10.3	3.3

FYPZ - Subsurface Water Well Samples
H.L.S. - Hospital Lake Slough
H.L. - Hospital Lake
Y.R. - Yukon River
P.R. - Porcupine River
S.L. - Sewage Lagoon
D. #1 - Surface Water at FYPZ-01
D. #2 - Surface Water at FYPZ-02
D. #3 - Surface Water at FYPZ-03

Table 2: Spring 2010 Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D. #1	D. #2	H.L.S.
Be	0.3	4.0	4.0	<LOD
Na	26.0	167612.6	267428.1	6969.9
Mg	41.2	83688.6	111142.6	18073.0
Al	0.4	8.5	14.8	5.4
K	37.0	50636.6	47377.7	3914.3
Ca	16.4	106867.3	175199.4	68731.0
V	0.6	0.9	1.3	0.9
Cr	0.1	2.2	2.3	0.4
Mn	0.2	210.5	1413.5	371.3
Fe	11.5	197.4	14707.9	122.3
Co	0.3	2.1	2.3	1.0
Ni	0.4	25.8	34.3	11.6
Cu	0.3	5.9	4.1	3.0
Zn	0.5	16.0	12.4	4.9
As	0.6	1.3	4.4	2.6
Se	0.5	0.6	0.5	<LOD
Mo	0.1	2.6	1.6	2.0
Ag	0.1	0.3	0.3	0.3
Cd	0.1	0.3	0.2	0.2
Sb	0.3	4.5	1.6	0.7
Ba	0.2	79.0	317.8	284.2
Ti	0.8	<LOD	<LOD	<LOD
Pb	0.3	<LOD	1.2	<LOD
Th	0.6	<LOD	<LOD	<LOD
U	0.9	<LOD	<LOD	1.0

D. #1 - Surface Water at FYPZ-01
D. #2 - Surface Water at FYPZ-02
H.L.S. - Hospital Lake Slough

Table 3: Spring 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	S.L.	H.L.	H.L.S.	O.S.L.	D. #2	D. #3	D. #1	Y.R.	FYPZ_01	FYPZ_02	FYPZ_03	FYPZ_04
Be	0.01	0.40	0.45	0.52	0.39	3.79	2.52	3.79	0.44	4.23	3.96	3.98	4.26
Na	128.07	18823.72	2528.71	2650.44	41278.16	89023.37	9135.34	475834.33	2462.79	51261.09	135350.50	658495.48	162069.20
Mg	30.13	39662.25	9043.68	10804.85	76031.70	105231.59	7021.73	195176.38	8225.32	28450.64	107187.87	113039.31	183252.66
Al	1.22	234.22	1350.78	2429.34	35.46	72.69	104220.20	91.84	1132.73	5229.99	1298.56	325.30	3305.28
Si	167.06	4098.65	5049.41	6075.87	5981.18	8711.29	59165.85	16053.31	4006.53	7406.07	6195.23	5635.39	7901.21
K	22.59	3882.41	2385.05	1918.19	18574.94	35066.23	2812.51	197393.34	1519.14	8415.62	19390.90	8825.08	8164.84
Ca	27.61	59785.99	38977.83	43864.09	30040.75	236759.17	16440.72	330630.21	30803.94	55528.36	96328.41	289725.94	123839.82
V	1.80	3.92	5.22	8.52	<LOD	<LOD	69.24	<LOD	4.02	20.66	<LOD	<LOD	18.04
Cr	0.29	0.51	3.19	5.31	<LOD	<LOD	116.45	<LOD	2.06	1061.20	106.01	14.08	16.28
Mn	0.36	1045.92	171.42	187.31	111.85	7026.99	2427.19	4002.45	90.16	6710.94	5445.88	2546.61	1553.21
Fe	52.48	1760.92	2294.89	4253.86	328.24	4997.95	265358.95	1912.80	1882.72	1879840.84	1663372.43	47135.07	155745.08
Co	0.93	3.27	1.97	3.40	<LOD	16.09	59.32	<LOD	1.64	71.31	19.87	18.74	14.30
Ni	2.04	20.31	13.05	17.82	9.07	50.46	1826.10	61.42	11.40	704.73	132.34	165.03	77.37
Cu	1.85	5.41	9.27	9.96	2.93	<LOD	148.51	<LOD	6.61	371.23	54.49	54.76	43.89
Zn	1.26	208.30	24.02	29.01	15.69	100.33	689.80	36.93	34.29	4369.86	4065.75	922.45	4116.88
As	0.37	4.79	2.58	2.92	2.41	8.87	4.09	8.08	1.81	10.13	5.41	6.13	5.47
Se	0.50	0.60	<LOD	<LOD	0.67	<LOD	<LOD	<LOD	0.50	<LOD	<LOD	<LOD	<LOD
Mo	0.60	3.86	0.89	0.85	4.11	<LOD	<LOD	13.54	0.98	7.75	<LOD	16.94	6.26
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	1.73	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	172.50	98.70	129.55	75.63	179.22	818.91	188.02	80.33	265.50	485.06	65.36	199.32
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	1.93	3.15	<LOD	<LOD	32.68	<LOD	1.84	18.89	<LOD	<LOD	15.07
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	7.07	1.38	1.62	5.40	6.53	8.41	11.32	1.48	12.56	11.28	9.04	11.50

FYPZ - Subsurface Water Well Samples
H.L.S. - Hospital Lake Slough
H.L. - Hospital Lake
Y.R. - Yukon River
O.S.L - Old Sewage Lagoon
S.L. - Sewage Lagoon
D. #1 - Surface Water at FYPZ-01
D. #2 - Surface Water at FYPZ-02
D. #3 - Surface Water at FYPZ-03

Table 4: Spring 2011 Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	H.L.S.	O.S.L.	D. #2	Y.R.1	D. #3	S.L.	H.L.	Y.R.2	D. #1	FYPZ_02	FYPZ_01	FYPZ_03
Be	0.01	0.40	0.38	0.39	0.39	0.38	0.23	0.21	0.19	0.71	0.59	0.71	0.38
Na	128.07	2672.15	40919.81	62911.43	2436.58	58626.71	32152.97	34853.73	16698.62	227017.44	987355.87	227017.44	74105.64
Mg	30.13	8212.73	76937.08	59524.25	7510.87	36252.85	23824.09	4654.66	38165.20	184035.09	1007539.42	184035.09	45043.25
Al	1.22	116.65	16.79	41.29	89.38	22.04	1274.43	456.41	226.20	487.29	260.60	487.29	13.99
Si	167.06	2706.63	5634.28	4404.40	2684.17	2490.56	1810.56	1179.39	767.78	10085.58	53250.02	10085.58	2179.59
K	22.59	1665.46	18409.18	11791.39	1416.58	13284.07	3077.58	492.47	1466.38	71974.64	463766.27	71974.64	16888.37
Ca	27.61	31037.65	28441.28	125597.80	28061.00	48136.64	21897.89	13414.62	14233.76	230711.21	1824592.70	230711.21	42103.92
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	5.76	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	1.30	1.20	1.00	<LOD	<LOD	2.30	<LOD	<LOD	<LOD	<LOD	<LOD	1.44
Mn	0.36	22.99	72.40	3198.79	21.31	270.30	275.44	132.21	151.34	2136.97	52272.49	2136.97	98.74
Fe	52.48	247.84	232.63	1947.78	222.75	3916.50	26768.16	6062.99	16008.05	11470.34	23683.33	11470.34	467.94
Co	0.93	<LOD	<LOD	8.87	<LOD	1.16	1.78	<LOD	<LOD	<LOD	52.64	<LOD	1.23
Ni	2.04	9.29	10.08	33.69	7.90	14.44	14.42	4.51	<LOD	52.19	321.86	52.19	15.44
Cu	1.85	4.58	2.92	2.62	5.21	5.03	<LOD	<LOD	<LOD	<LOD	30.63	<LOD	4.63
Zn	1.26	5.76	7.25	26.63	3.93	24.86	57.98	526.27	129.33	153.78	153.46	153.78	9.25
As	0.37	0.98	2.45	3.52	0.92	1.39	0.78	0.67	<LOD	<LOD	29.56	<LOD	1.09
Se	0.50	0.51	0.69	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	6.73	<LOD	<LOD
Mo	0.60	1.20	5.86	1.10	1.12	2.36	<LOD	0.68	<LOD	<LOD	35.80	<LOD	3.29
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	4.53	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	3.01	<LOD	<LOD	<LOD	<LOD	20.55	<LOD	3.45
Ba	1.05	38.96	70.97	170.95	40.56	58.88	200.38	12.95	49.05	1037.39	1688.57	1037.39	33.40
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	1.20	4.00	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.58	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	1.43	9.28	0.73	1.40	0.98	0.79	1.83	<LOD	<LOD	27.82	<LOD	1.10

FYPZ - Subsurface Water Well Samples
H.L.S. - Hospital Lake Slough
H.L. - Hospital Lake
Y.R. - Yukon River
O.S.L - Old Sewage Lagoon
S.L. - Sewage Lagoon
D. #1 - Surface Water at FYPZ-01
D. #2 - Surface Water at FYPZ-02
D. #3 - Surface Water at FYPZ-03

Table 4: Fall 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	H.L.	Y.R.	D. #1	FY-Sump_01	FY-Sump_02	FYPZ_01	FYPZ_02	FYPZ_03	FYPZ_04	FYPZ_02	FYPZ_03	FYPZ_04	FY-Sump_01	FY-Sump_02
Be	0.01	<LOD	<LOD	<LOD	2.87	5.30	5.99	3.61	0.46	<LOD	0.5	0.5	<LOD	<LOD	<LOD
Na	128.07	2495.9	3301.3	144039.6	5818.88	21720.92	60043.13	10513.45	135335.96	58720.2	281824.4	316925.6	43215.8	208797.0	87044.6
Mg	30.13	9345.4	11608.7	131738.4	2445.06	91494.59	32727.45	56092.09	32310.20	112497.0	209772.0	42811.0	100278.3	171282.6	89476.4
Al	1.22	29.2	1213.5	504.3	82134.15	46841.05	35498.40	30057.27	37.90	4106.5	11327.7	4195.7	597.4	456.2	22.1
Si	167.06	1922.2	5311.2	51776.4	50011.03	33726.82	24232.10	28607.35	6070.64	9478.9	18832.9	10705.7	<LOD	9079.8	5676.0
K	22.59	1984.4	1467.4	26928.3	1465.80	1018.28	254.32	1180.93	6725.95	4680.5	28449.5	4804.8	4051.4	70119.1	44333.6
Ca	27.61	36690.2	38980.8	429435.9	9242.60	332585.46	185964.59	250971.47	130039.77	68096.2	240999.7	128900.5	41541.4	221078.1	147413.8
V	1.80	<LOD	3.9	<LOD	49.35	81.09	22.36	54.42	<LOD	<LOD	55.4	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	2.2	<LOD	33.01	121.23	61.51	48.36	<LOD	18.1	28.7	<LOD	<LOD	<LOD	<LOD
Mn	0.36	79.4	79.0	7599.8	1150.20	2378.50	2909.78	4884.11	1848.22	2029.7	2492.5	1246.8	409.9	2031.4	4999.2
Fe	52.48	656.8	1925.7	979469.0	180035.14	40872.93	117419.23	45455.46	5462.26	239572.3	277993.7	54737.4	44873.5	10169.2	2210.7
Co	0.93	<LOD	1.1	<LOD	9.56	54.80	48.42	58.73	<LOD	12.7	14.9	<LOD	<LOD	<LOD	4.9
Ni	2.04	7.6	11.7	110.1	52.67	383.76	213.77	204.11	24.56	<LOD	74.0	<LOD	<LOD	<LOD	20.0
Cu	1.85	<LOD	4.3	46.7	52.02	116.23	138.49	198.26	<LOD	59.4	<LOD	<LOD	<LOD	<LOD	3.1
Zn	1.26	2.7	13.0	421.7	11882.55	1391.24	5880.40	1283.26	<LOD	433.6	551.5	5506.8	376.4	156.6	14.9
As	0.37	2.0	1.2	9.0	<LOD	5.21	<LOD	6.67	7.22	<LOD	7.1	6.2	<LOD	<LOD	2.5
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	7.2	<LOD	<LOD	3.4
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	4.66	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.9
Ba	1.05	76.0	72.2	10328.8	234.04	310.32	1339.53	1340.65	74.94	399.3	1667.9	111.4	119.7	962.0	163.9
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	0.8	<LOD	19.45	27.04	27.08	63.49	<LOD	19.7	12.8	38.7	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	12.0	<LOD	<LOD	<LOD
U	0.23	0.3	1.1	3.9	8.41	22.59	7.21	<LOD	<LOD	10.6	6.9	16.9	<LOD	<LOD	2.6

FYPZ - Subsurface Water Well Samples Y.R. - Yukon River
FY-Sump - Subsurface Water Soil Pit D. #1 - Surface Water at FYPZ-01
H.L. - Hospital Lake

Table 5: Fall 2011 Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	H.L.	Y.R.	D. #1	FY-Sump_01	FY-Sump_02	FYPZ_01	FYPZ_02	FYPZ_03	FYPZ_04
Be	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Na	128.07	2402.6	3111.2	12702.5	22573.6	15248.0	17968.0	13747.3	24122.5	6181.4
Mg	30.13	9166.1	10461.2	10549.8	18203.5	11528.7	10024.1	7108.3	3522.7	3971.3
Al	1.22	5.6	52.4	<LOD	<LOD	<LOD	1.8	<LOD	5.2	<LOD
Si	167.06	1780.4	3615.1	696.5	753.4	419.4	260.2	314.0	<LOD	<LOD
K	22.59	1971.9	1273.6	1883.5	5476.1	11946.1	1735.4	840.6	180.3	349.5
Ca	27.61	34559.0	33898.9	15196.2	14607.3	16932.9	11231.8	9332.7	10312.8	1659.3
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	<LOD	<LOD	<LOD	<LOD	<LOD	0.4	<LOD	<LOD	<LOD
Mn	0.36	7.1	11.4	199.4	76.0	95.0	87.9	69.4	52.5	2.1
Fe	52.48	467.9	<LOD	1747.7	565.7	251.8	188.5	<LOD	<LOD	<LOD
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	2.04	7.7	7.2	3.9	3.5	3.2	3.5	2.6	<LOD	<LOD
Cu	1.85	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Zn	1.26	1.5	1.6	<LOD	2.1	<LOD	2.5	<LOD	<LOD	<LOD
As	0.37	1.6	0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	<LOD	1.1	<LOD	<LOD	<LOD	<LOD	<LOD	0.9	2.7
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	74.1	46.3	34.6	32.1	13.9	13.2	12.0	5.1	1.6
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	0.3	1.1	<LOD	0.3	0.8	<LOD	<LOD	1.2	<LOD

FYPZ - Subsurface Water Well Samples
FY-Sump - Subsurface Water Soil Pit
H.L. - Hospital Lake
Y.R. - Yukon River
D. #1 - Surface Water at FYPZ-01

Table 6: Summer 2010 Anion Metal Analysis (ppm)

Analyte	LOD	FY-Sump_01	FYPZ_04	D. #1	D. #2	S.L.	Y.R.	H.L.S.
F^-	0.01	0.07	0.27	0.18	0.16	0.31	0.12	0.12
Cl^-	0.17	710.97	52.41	224.41	634.55	13.35	0.57	1.68
NO_2^-	0.06	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.14	408.71	75.07	384.00	482.58	42.04	43.00	14.36
Br^-	0.11	12.50	<LOD	0.92	10.58	0.45	<LOD	<LOD
NO_3^-	0.04	5.44	<LOD	4.64	4.47	<LOD	<LOD	<LOD
PO_4^{-3}	0.28	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

FYPZ - Subsurface Water Well Samples
H.L.S. - Hospital Lake Slough
FY-Sump - Subsurface Water Soil Pit
Y.R. - Yukon River
D. #1 - Surface Water at FYPZ-01
D. #2 - Surface Water at FYPZ-02
D. #3 - Surface Water at FYPZ-03
S.L. - Sewage Lagoon

Table 7: Spring 2011 Anion Metal Analysis (ppm)

Analyte	LOD	S.L.	H.L.	D. #2	Y.R.	O.S.L.	FYPZ_03	FYPZ_01	FYPZ_02	D. #1
F^-	0.06	0.38	0.11	0.08	0.11	0.30	0.12	0.31	0.07	0.09
Cl^-	0.10	14.99	0.58	34.90	0.64	50.14	99.33	389.60	93.29	240.61
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.30
SO_4^{-2}	0.23	26.34	21.49	2.18	30.63	84.17	438.41	804.24	49.22	210.76
Br^-	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.20	0.28	1.32
NO_3^-	0.30	<LOD	<LOD	0.49	<LOD	<LOD	<LOD	<LOD	<LOD	6.66
PO_4^{-3}	0.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

FYPZ - Subsurface Water Well Samples
H.L. - Hospital Lake
FY-Sump - Subsurface Water Soil Pit
D. #1 - Surface Water at FYPZ-01
D. #2 - Surface Water at FYPZ-02
Y.R. - Yukon River
S.L. - Sewage Lagoon

Table 8: Fall 2011 Anion Metal Analysis (ppm)

Analyte	LOD	H.L.	Y.R.	D. #1	FY-Sump_01	FY-Sump_02	FYPZ_01	FYPZ_02	FYPZ_03	FYPZ_04	FYPZ_02	FYPZ_03	FYPZ_04	FY-Sump_01	FY-Sump_02
F^-	0.06	0.11	0.16	0.07	0.08	0.10	0.07	5.50	0.36	0.25	0.17	0.42	0.42	0.06	<LOD
Cl^-	0.10	0.69	0.58	97.82	223.41	188.66	272.81	214.38	524.87	28.06	210.63	125.92	43.47	201.53	6.89
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.23	13.21	39.75	4.24	22.13	131.52	16.24	7.07	1573.21	35.56	17.92	331.42	27.49	70.31	1.78
Br^-	0.07	<LOD	<LOD	<LOD	1.59	1.68	1.92	0.81	<LOD	<LOD	1.04	<LOD	0.13	0.80	<LOD
NO_3^-	0.30	<LOD	<LOD	<LOD	<LOD	0.58	0.95	0.47	0.74	0.62	<LOD	0.31	<LOD	24.04	<LOD
PO_4^{-3}	0.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

FYPZ - Subsurface Water Well Samples
H.L. - Hospital Lake
D. #1 - Surface Water at FYPZ-01
Y.R. - Yukon River
FY-Sump - Subsurface Water Soil Pit

Appendix C-v: ICP-MS Metal Analysis Data for White Mountain

Table 1: Spring 2010 Total (T) Metal Analysis (ppb)

Analyte	LOD	D.S.	F.R.	V.C.	D. 1	D.2	D.3	D.4	D.D.	D.#1
Be	0.3	<LOD	<LOD	<LOD	0.3	0.6	4.1	7.4	2.4	1.9
Na	26.0	39580.6	2070.1	2403.4	3280.0	3384.7	633359.9	4665.0	2340.3	2266.0
Mg	41.2	33468.4	3649.8	6872.3	4427.2	8464.0	177627.8	88629.5	113514.6	110465.4
Al	0.4	2.1	253.3	54.1	289.7	2922.5	554.6	32352.8	12178.9	9815.2
K	37.0	277.0	1862.9	1755.1	992.0	672.7	263638.8	2914.4	693.6	926.9
Ca	16.4	76186.4	10178.7	13230.5	10806.6	24883.4	463479.5	307675.4	247912.7	242599.0
V	0.6	0.9	1.4	1.0	1.6	9.1	10.3	93.6	18.8	19.5
Cr	0.1	0.6	0.7	0.5	1.1	3.7	21.0	25.7	9.6	8.2
Mn	0.2	1.0	27.2	7.1	81.2	491.2	13397.1	4708.1	1484.8	1299.3
Fe	11.5	41.4	393.6	105.3	529.2	2859.0	5656.9	8138.9	2717.3	2806.5
Co	0.3	0.8	0.5	0.3	0.7	2.9	46.3	37.5	13.8	12.6
Ni	0.4	11.4	1.9	2.5	2.7	7.5	144.1	67.4	47.7	46.1
Cu	0.3	16.6	2.9	3.1	8.4	8.6	81.7	57.3	18.9	17.2
Zn	0.5	68.0	11.2	25.1	11.4	31.8	523.9	291.5	71.2	74.6
As	0.6	0.7	1.0	1.1	1.1	1.7	7.4	3.0	1.7	1.8
Se	0.5	<LOD	<LOD	0.8	<LOD	1.4	10.4	3.6	1.9	1.8
Mo	0.1	<LOD	<LOD	<LOD	<LOD	<LOD	4.6	<LOD	<LOD	<LOD
Ag	0.1	0.3	0.3	0.4	0.4	0.4	32.1	0.3	0.3	0.3
Cd	0.1	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.3	0.3
Sb	0.3	0.2	0.3	0.2	0.3	0.4	2.9	5.6	1.4	1.3
Ba	0.2	0.6	0.6	0.7	0.9	0.8	195.8	1.1	0.7	0.7
Ti	0.8	40.3	10.0	11.4	13.0	111.2	309.1	2270.8	648.1	512.4
Pb	0.3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	0.6	0.7	0.9	0.6	1.7	6.5	3.1	37.3	13.0	18.2
U	0.9	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.6	0.6	0.6
		<LOD	<LOD	<LOD	<LOD	<LOD	2.6	1.2	<LOD	<LOD

D.S. - Drinking Water Source
F.R. - Fish River
V.C. - Village Creek
D.1 - Surface Water at Decomposed Waste
D-2 - Surface Water at Newly Disposed Waste
D-3 - Surface Water at Dump Drainage
D-4 - Surface Water at Burnbox
D. #1 - Surface Water at WMOPZ
D.D. - Surface at Dump Drainage

Table 2: Spring 2011 Total (T) Metal Analysis (ppb)

Analyte	LOD	D.4	D.3	D.D.	D.1	D.5	D.6	D.2	F.R.	WMO-Sump-02	WMO-Sump-02
Be	0.01	0.44	0.39	1.03	0.59	0.48	0.55	0.10	0.10	0.21	1.73
Na	128.07	3432.00	1849.96	11021.49	34000.55	371457.31	165045.07	16333.64	6251.98	25070.45	300238.65
Mg	30.13	9668.95	11039.93	32697.59	42985.14	45606.85	125417.78	9566.27	11980.12	17697.42	42631.84
Al	1.22	301.30	122.35	8339.74	2241.44	78.43	286.44	497.94	443.62	1487.04	4938.57
Si	167.06	2408.00	2949.13	13192.34	13539.65	1859.42	5891.94	1004.79	998.71	2359.12	9523.64
K	22.59	2126.61	1347.19	1121.65	14882.48	13205.70	125325.92	1583.73	485.28	2443.02	2611.24
Ca	27.61	20695.69	19392.18	81361.78	128792.58	19216.50	198531.85	10587.83	6909.45	17974.25	126495.76
V	1.80	<LOD	<LOD	20.85	<LOD	<LOD	<LOD	<LOD	<LOD	5.07	<LOD
Cr	0.29	17.79	6.42	5.47	<LOD	<LOD	<LOD	4.78	1.52	5.70	9.47
Mn	0.36	16.33	157.66	1456.31	2474.25	8.85	984.21	179.04	212.36	210.60	839.88
Fe	52.48	305.56	182.90	7321.56	3145.82	875.05	6174.76	34155.28	26650.28	21934.16	21769.74
Co	0.93	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.52	1.41	1.94	<LOD
Ni	2.04	21.81	10.15	24.90	39.16	<LOD	39.98	10.02	7.26	14.44	49.58
Cu	1.85	6.27	<LOD	<LOD	<LOD	<LOD	<LOD	3.70	5.27	4.77	<LOD
Zn	1.26	48.45	18.21	80.00	92.42	13.71	33.05	149.48	42.68	59.59	107.46
As	0.37	0.74	0.65	4.10	15.75	<LOD	3.74	0.58	0.37	1.04	5.89
Se	0.50	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mo	0.60	1.92	1.12	<LOD	9.02	<LOD	6.78	<LOD	<LOD	<LOD	<LOD
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	17.44	9.60	216.39	152.51	<LOD	220.59	53.11	45.14	132.42	119.05
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	14.49	<LOD	<LOD	<LOD	1.53	1.95	2.66	16.91
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	0.67	0.67	<LOD	<LOD	<LOD	13.52	1.49	1.20	1.54	25.84

WMO-Sump - Subsurface Water from Soil Pit
F.R. - Fish River
D.D. - Surface Water at Dump Drainage
D.1 - Surface Water at Decomposed Waste
D-2 - Surface Water at Newly Disposed Waste
D-3 - Surface Water at Mid Dump
D-4 - Surface Water at Burnbox
D-5 - Creek Upgradient from Dump
D-6 - Surface Water at Decomposed Waste

Table 3: Spring 2011 Dissolved (D) Metal Analysis (ppb)

Analyte	LOD	D.4	D.3	D.D.	D.1	D.5	D.6	D.2	F.R.	WMO-Sump-02	WMO-Sump-02
Be	0.01	0.06	0.05	0.09	0.39	0.43	0.39	0.05	0.05	0.11	0.07
Na	128.07	20967.80	9944.03	3026.34	44421.01	3372.69	1892.49	4889.14	1241.20	3248.57	5932.39
Mg	30.13	24317.34	24103.26	5960.87	33943.25	9604.76	11399.63	22942.16	1777.23	2819.38	8251.71
Al	1.22	69.60	36.59	188.76	47.50	275.33	18.31	18.69	39.23	691.57	242.31
Si	167.06	7033.30	3811.00	2792.82	4210.80	2326.49	2878.66	7775.89	1396.49	1854.14	3934.74
K	22.59	9004.70	1233.90	1462.50	9984.16	2088.82	1242.26	1450.07	750.94	871.66	604.56
Ca	27.61	74740.17	62162.76	11537.01	92617.20	20411.96	19917.09	51406.12	10924.37	7486.95	24856.96
V	1.80	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cr	0.29	1.05	0.63	2.08	2.99	12.27	0.96	1.28	1.01	1.78	1.12
Mn	0.36	1580.58	972.50	8.11	1990.62	11.99	95.83	140.04	8.71	98.96	25.57
Fe	52.48	354.99	95.25	298.53	224.14	274.21	57.00	162.01	193.86	756.46	317.54
Co	0.93	3.63	1.19	<LOD	4.46	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ni	2.04	23.80	14.05	4.43	24.16	10.01	4.30	11.07	3.35	3.35	5.91
Cu	1.85	7.58	7.91	7.16	9.93	6.49	<LOD	<LOD	<LOD	<LOD	3.00
Zn	1.26	11.74	2.68	7.14	40.05	41.50	5.58	7.13	2.78	9.85	10.17
As	0.37	9.27	1.42	0.44	2.92	0.69	0.58	1.01	0.40	0.56	0.68
Se	0.50	0.90	0.75	0.53	<LOD	<LOD	<LOD	0.56	<LOD	0.55	0.54
Mo	0.60	5.50	2.18	<LOD	6.88	1.53	0.70	1.01	<LOD	<LOD	0.91
Ag	0.83	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cd	0.38	<LOD	<LOD	<LOD	0.39	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sb	1.72	3.88	<LOD	<LOD	6.72	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Ba	1.05	83.18	38.22	8.43	96.54	17.40	7.68	19.35	7.10	16.43	14.39
Ti	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Pb	0.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Th	1.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
U	0.23	1.15	1.24	<LOD	1.47	0.68	0.68	1.00	<LOD	<LOD	<LOD

WMO-Sump - Subsurface Water from Soil Pit
F.R. - Fish River
D.D. - Surface Water at Dump Drainage
D.1 - Surface Water at Decomposed Waste
D-2 - Surface Water at Newly Disposed Waste
D-3 - Surface Water at Mid Dump
D-4 - Surface Water at Burnbox
D-5 - Creek Upgradient from Dump
D-6 - Surface Water at Decomposed Waste

Table 4: Spring 2010 Anion Metal Analysis (ppm)

Analyte	LOD	D-1	D-4	D.D.	D-3	D-2
F^-	0.01	0.04	0.06	<LOD	0.04	0.24
Cl^-	0.17	2.14	4.01	920.59	2.05	84.72
NO_2^-	0.06	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.14	1.37	6.33	944.58	1.47	11.10
Br^-	0.11	<LOD	<LOD	5.36	<LOD	0.20
NO_3^-	0.04	0.43	2.10	<LOD	0.34	4.09
PO_4^{-3}	0.28	<LOD	<LOD	<LOD	<LOD	<LOD

D.1 - Surface Water at Decomposed Waste
D-2 - Surface Water at Newly Disposed Waste
D.D. - Surface Water at Dump Drainage
D-3 - Surface at Mid Dump
D-4 - Surface Water at Burnbox

Table 5: Spring 2011 Anion Metal Analysis (ppm)

Analyte	LOD	D.D.	D-3	D-4	D-1	D-5	D-6	D-2	WMO-Sump_02	WMO-Sump_01	F.R.
F^-	0.06	<LOD	0.13	0.09	<LOD	<LOD	0.06	0.07	<LOD	<LOD	<LOD
Cl^-	0.10	3.71	14.01	25.94	45.80	3.46	4.79	6.88	4.39	4.08	1.51
NO_2^-	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
SO_4^{-2}	0.23	1.53	25.08	28.62	128.23	1.87	7.31	5.74	1.91	3.72	3.50
Br^-	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
NO_3^-	0.30	<LOD	0.85	<LOD	<LOD	<LOD	0.43	0.65	<LOD	<LOD	<LOD
PO_4^{-3}	0.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

WMO-Sump - Subsurface Water from Soil Pit
F.R. - Fish River
D.D. - Surface Water at Dump Drainage
D.1 - Surface Water at Decomposed Waste
D-2 - Surface Water at Newly Disposed Waste
D-3 - Surface Water at Mid Dump
D-4 - Surface Water at Burnbox
D-5 - Creek Upgradient from Dump
D-6 - Surface Water at Decomposed Waste

Appendix C-v.: ICP-MS Inorganic Data Summary

Metal Constitutes	Mean Landfill Surface Water Concentrations		Mean Landfill Subsurface Water Concentrations		Mean Control Water Concentrations		EPA Drinking Water Standards	Solid Waste Leachate (USEPA 1998)
	Min	Max	Min	Max	Min	Max	Range	Range
Beryllium (ppb)	0.4	1.6	0.1	3.5	0.1	2.0	4.0	1.0-10.0
Sodium (ppm)	7.3	153.9	8.7	178.4	3.1	8.4		12.0-2,574
Magnesium (ppm)	2.9	79.4	1.4	107.6	0.9	20.5		120-780.0
Aluminum (ppm)	0.2	13.6	2.9	30.9	0.1	0.5	0.05-0.2	74.0-927.0
Potassium (ppm)	7.6	45.4	1.0	19.1	0.9	3.2		17.8-1,175
Calcium (ppm)	13.6	165.4	4.6	205.7	3.5	57.1		95.9-2,100
Vanadium (ppm)	2.5	30.2	5.1	94.5	0.7	3.1		9.0-29.0
Chromium (ppb)	0.6	59.6	7.6	90.2	0.2	2.9	100.0	0.5-1,900
Manganese (ppm)	0.2	2.5	0.5	2.7	0.1	0.7	0.1	0.03-79.0
Iron (ppm)	5.6	196.9	21.9	356.9	0.7	13.4	0.3	0.22-2,280
Cobalt (ppm)	0.9	20.3	1.9	50.0	0.4	2.1		40.0-130.0
Nickel (ppb)	3.3	262.8	32.0	484.0	ND	12.4	100.0	20.0-2,227.0
Copper (ppb)	14.3	70.7	4.8	195.5	1.7	45.4	1000.0	3.0-2,800
Zinc (ppb)	114.8	386.2	83.5	3,576.5	10.9	50.9	5.0	0.03-350
Arsenic (ppb)	2.2	6.4	1.0	7.5	0.7	2.3	10.0	0.2-982.0
Selenium (ppm)	ND	14.4	ND	4.12	ND	0.8	5.0	ND-1,850
Molybdenum (ppm)	ND	8.2	ND	6.3	ND	2.2		10.0-1,430
Silver (ppm)	ND	0.4	ND	0.3	ND	0.3	100.0	ND-1,960
Cadmium (ppb)	0.3	3.1	ND	5.9	0.1	0.3	50.0	0.7-150
Antimony (ppm)	0.5	33.3	ND	1.9	0.2	1.3	6.0	1.5-47,000
Barium (ppb)	30.7	3,641.3	125.7	567.5	8.6	107.7	2000.0	80.0-5,000
Thallium (ppm)	ND	0.2	ND	ND	ND	0.8	2.0	ND-780.0
Lead (ppb)	4.9	20.9	9.8	39.4	0.8	2.1	15.0	5.0-1,600
Thorium (ppm)	ND	3.9	ND	13.7	ND	0.5		
Uranium (ppm)	ND	4.5	0.02	13.0	ND	3.2		
Fluoride (ppm)	0.03	108.8	0.05	4.2	0.05	7.0	2.0	0.11-302
Chloride (ppm)	ND	411.7	ND	253.8	ND	9.3	250.0	31.0-5,475
Nitrite (ppm)	ND	381.6	ND	11.5	ND	12.3	1.0	ND-1,460
Sulfate (ppm)	2.8	166.5	ND	291.9	ND	124.3	250.0	8.0-1,400
Bromide (ppm)	ND	3.5	ND	4.6	ND	0.4	10.0	
Nitrate (ppm)	ND	4.1	ND	2.8	ND	0.5	10.0	ND-250,000
Phosphorus (ppm)	ND	2.3	ND	0.6	ND	0.4	0.1*	0.29-117.2
pH (units)	5.8	8.7	6.2	10.3	5.7	8.1	6.5-8.5	5.0-8.9
Specific Conductance (mmhos/cm)	77	2,232	400	2,300	14	444		480-72,500
*Total Alkalinity ($CaCO_3$) (ppm)	20	240	40	240	20	120		
*Total Hardness ($CaCO_3$) (ppm)	50	425	25	425	25	250		
Total Suspended Solids (ppm)	9.5	4,247	53.3	29,012	2.7	159.5	500.0	23-17,800
Total Organic Carbon (ppm)	4.4	174.8	0.8	167.4	0.8	13.8		20.0-14,500

ND = not detected

Appendix D: Microbial Indicator Organism Analysis Data

Appendix D-i: Microbial Indicator Organism Data for Allakaket

Table 1: Microbial Indicator Organisms Water Data Summer 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D1	N66 ^{0}31.701' W152^0 39.874'	18.2	7.8	125.4	2419.6	2.1	3.4
D1	N66^0 31.711' W152^0 39.835'	18.2	7.8	110.6	2419.6	2.0	3.4
D1	N66^0 31.711' W152^0 39.835'	18.2	7.8	108.1	2419.6	2.0	3.4
D5	N66^0 31.701' W152^0 39.874'	11.3	6.1	14.6	1732.9	1.2	3.2
D5	N66^0 31.701' W152^0 39.874'	11.3	6.1	14.2	980.4	1.2	3.0
D5	N66^0 31.701' W152^0 39.874'	11.3	6.1	12.0	2419.6	1.1	3.4
D4	N66^0 31.711' W152^0 39.835'	14.6	6.2	74.3	1732.9	1.9	3.2
D4	N66^0 31.711' W152^0 39.835'	14.6	6.2	106.7	2419.6	2.0	3.4
D4	N66^0 31.711' W152^0 39.835'	14.6	6.2	84.2	2419.6	1.9	3.4
O.D.	N66^0 32.953' W152^0 38.539'	17.6	7.0	290.9	30.7	2.5	1.5
O.D.	N66^0 32.953' W152^0 38.539'	17.6	7.0	86.5	24.8	1.9	1.4
O.D.	N66^0 32.953' W152^0 38.539'	17.6	7.0	77.1	34.6	1.9	1.5
O.D.	N66^0 32.953' W152^0 38.539'	17.6	7.0	112.4		2.1	1.5
S.T.O.	N66^0 32.760' W152^0 38.723'	17.2	7.2	2.0	4.1	0.3	0.6
S.T.O.	N66^0 32.760' W152^0 38.723'	17.2	7.2	3.0	4.1	0.5	0.6
S.T.O.	N66^0 32.760' W152^0 38.723'	17.2	7.2	4.0	8.4	0.6	0.9
K.R.	N66^0 32.933' W152^0 39.772'	16.1	7.8	344.8	178.5	2.5	2.3
K.R.	N66^0 32.933' W152^0 39.772'	16.1	7.8	298.7	218.7	2.5	2.3
K.R.	N66^0 32.933' W152^0 39.772'	16.1	7.8	344.8	114.5	2.5	2.1
D.W.	N66^0 32.939' W152^0 39.711'	14.7	7.5	224.7	137.4	2.4	2.1
D.W.	N66^0 32.939' W152^0 39.711'	14.7	7.5	110.4	113.7	2.0	2.1
S.K.R.	N66^0 32.876' W152^0 38.062'	19.3	7.0	1.0	5.2	0.0	0.7
S.K.R.	N66^0 32.876' W152^0 38.062'	19.3	7.0	2.0	14.9	0.3	1.2
A.S.	N66^0 33.893' W152^0 38.442'	17.6	7.0	135.4	32.5	2.1	1.5
A.S.	N66^0 33.893' W152^0 38.442'	17.6	7.7	142.1	52.9	2.2	1.7
A.S.	N66^0 33.893' W152^0 38.442'	17.6	7.7	128.1	52.9	2.1	1.7
D.W.S.		R.T.	7.3	0.0	0.0	0.0	0.0

D-1 - Surface Water Dump (Left) O.D. - Old Dump D-4 - Surface Water Dump Drainage (Right)
S.T.O. - Slough behind Tribal Office K.R. - Koyukuk River D.W. - Surface Water at Drinking Water Well
S.K.R. - Slough entering Koyukuk River A.S. - Slough at Airport D.W.S. - Drinking Water Source
D-5 - Surface Water Dump Drainage (Left)

Table 2: Microbial Indicator Organisms Water Data Fall 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D3	N66^0 31.702' W152^0 39.329'	18.2	7.8	80.8	2419.6	1.9	3.4
D3	N66^0 31.702' W152^0 39.329'	18.2	7.8	58.3	2419.6	1.8	3.4
D3	N66^0 31.702' W152^0 39.329'	18.2	7.8	66.6	2546.9	1.8	3.4
D5	N66^0 31.727' W152^0 39.892'	16.6	8.4	32.3	24.1	1.5	1.4
D5	N66^0 31.727' W152^0 39.892'	16.6	8.4	27.5	41.4	1.4	1.6
D5	N66^0 31.727' W152^0 39.892'	16.6	8.4	51.6	30.2	1.7	1.5
D4	N66^0 31.704' W152^0 39.866'	15.9	7.4	290.9	2.0	2.5	0.3
D4	N66^0 31.704' W152^0 39.866'	15.9	7.4	248.1	4.1	2.4	0.6
D4	N66^0 31.704' W152^0 39.866'	15.9	7.4	275.1	0.0	2.4	0.0
D2	N66^0 31.719' W152^0 39.868'	15.8	7.9	103.9	3.0	2.0	0.5
D2	N66^0 31.719' W152^0 39.868'	15.8	7.9	116	6.1	2.1	0.8
D2	N66^0 31.719' W152^0 39.868'	15.8	7.9	89.4	17.2	2.0	1.2
K.R.	N66^0 32.933' W152^0 39.772'	15.2	7.9	6.3	1.0	0.8	0.0
K.R.	N66^0 32.933' W152^0 39.772'	15.2	7.9	14.6	0.0	1.2	0.0
D.W.	N66^0 32.939' W152^0 39.711'	17.3	7.7	1.0	0.0	0.0	0.0
D.W.	N66^0 32.939' W152^0 39.711	17.3	7.7	0.0	0.0	0.0	0.0
D.W.S.			7.3	0.0	0.0	0.0	0.0

D-3 - Surface Water Dump (Mid) D.W.S. - Drinking Water Source K.R. - Koyukuk River
D.2 - Surface Water (Open Burning) D.W. - Surface Water at Drinking Water Well
D-4 - Surface Water Dump Drainage (Right) D-5 - Surface Water Dump Drainage (Left)

Table 3: Microbial Indicator Organisms Soil Data Summer 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N66^0 31.713' W152^0 39.830'	18.2	4.2	57.1	0.6	1.8
S1	N66^0 31.713' W152^0 39.830'	18.2	0.0	20.8	0.0	1.3
S1	N66^0 31.713' W152^0 39.830'	18.2	4.2	25.4	0.6	1.4
S2	N66^0 31.722' W152^0 39.831'	11.3	563.8	3836.7	2.8	3.6
S2	N66^0 31.722' W152^0 39.831'	11.3	463.3	2861.3	2.7	3.5
S2	N66^0 31.722' W152^0 39.831'	11.3	920.4	669.6	3.0	2.8
S3	N66^0 31.720' W152^0 39.843'	14.6	4.2	125.8	0.6	2.1
S3	N66^0 31.720' W152^0 39.843'	14.6	33.3	123.3	1.5	2.1
S3	N66^0 31.720' W152^0 39.843'	14.6	46.7	153.3	1.7	2.2
S4	N66^0 31.734' W152^0 39.885'	17.6	21.3	527.9	1.3	2.7
S4	N66^0 31.734' W152^0 39.885'	17.6	45.4	467.5	1.7	2.7
S4	N66^0 31.734' W152^0 39.885'	17.6	17.1	230.0	1.2	2.4
S5	N66^0 31.755' W152^0 39.887'	17.6	4.2	50.0	0.6	1.7
S5	N66^0 31.755' W152^0 39.887'	17.2	8.3	45.8	0.9	1.7
S5	N66^0 31.755' W152^0 39.887'	17.2	29.2	29.2	1.5	1.5
S6	N66^0 31.758' W152^0 39.850'	17.2	16.7	326.3	1.2	2.5
S6	N66^0 31.758' W152^0 39.850'	16.1	20.8	137.1	1.3	2.1
S6	N66^0 31.758' W152^0 39.850'	16.1	47.5	131.7	1.7	2.1
C	N66^0 31.720' W152^0 39.865'	16.1	0.0	73.3	0.0	1.9
C	N66^0 31.720' W152^0 39.865'	14.7	0.0	77.9	0.0	1.9
C	N66^0 31.720' W152^0 39.865'	14.7	29.2	76.3	1.5	1.9

S1 - Soil Sample at Dump Drainage Upgradient S4 - Soil Sample at Dump Drainage Down-gradient
S2 - Soil Sample at Decomposed Waste S5 - Soil Sample at Electrical Waste
S3 - Soil Sample at Construction Waste S6 - Soil Sample at Burnbox
C - Soil Sample at Control Site

Table 4: Microbial Indicator Organisms Soil Data Fall 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S2	N66^0 31.727' W152^0 39.818'	0.20	0.0	173.0	0.0	2.2
S2	N66^0 31.727' W152^0 39.818'	0.20	0.0	244.5	0.0	2.4
S3	N66^0 31.724' W152^0 39.812'	0.20	4604.0	12098.0	3.7	4.1
S3	N66^0 31.724' W152^0 39.812'	0.20	12098.0	12098.0	4.1	4.1
S6	N66^0 31.758' W152^0 39.850'	0.20	214.0	12098.0	2.3	4.1
S6	N66^0 31.758' W152^0 39.850'	0.20	91.5	164.5	2.0	2.2
C	N66^0 31.755' W152^0 39.843'	0.20	0.0	31.0	0.0	1.5
C	N66^0 31.755' W152^0 39.843'	0.20	5.0	20.5	0.7	1.3

S1 - Soil Sample at Dump Drainage Upgradient
S2 - Soil Sample at Decomposed Waste
S3 - Soil Sample at Construction Waste
C - Soil Sample at Control Site
S5 - Soil Sample at Electrical Waste
S4 - Soil Sample at Dump Drainage Down-gradient
S6 - Soil Sample at Burnbox

Appendix D-ii: Microbial Indicator Organism Data for Eek

Table 1: Microbial Indicator Organisms Water Data Fall 2009

Sample ID.	GPS Location	MPN/100mL		Log Mean MPN/100mL	
		EC	ENT	EC	ENT
V.P.-3	N60^0 13.019' W162^0 01.717'	0.0	5.1	0.0	0.7
V.P.-2	N60^0 13.021' W162^0 01.897'	2.0	2419.6	0.3	3.4
V.P-1	N60^0 13.082' W162^0 01.681'	0.0	0.0	0.0	0.0
D.	N60^0 12.751' W162^0 01.641'	25.9	6.0	0.9	0.8
S.L.	N60^0 12.784' W162^0 01.819'	275.5	2419.6	2.4	3.4
D.D.	N60^0 12.745' W162^0 01.635'	0.0	0.0	0.0	0.0
D.D.	N60^0 12.731' W162^0 01.554'	6.3	461.1	1.4	2.7
A.L.	N60^0 12.680' W162^0 01.886'	7.5	2419.6	1.4	3.4
B.L.	N60^0 12.734' W162^0 01.548'	0.0	2.0	0.0	0.3
S.L.D-1	N60^0 12.826' W162^0 01.865'	0.0	2.0	0.0	0.3
S.L.D-2	N60^0 12.707' W162^0 01.904'	31.5	2419.6	1.5	3.4
D.W.S.	N60^0 12.734' W162^0 01.548'	0.0	2.0	0.0	0.3

D. - Dump A.L. - Airport Lake O.A.P. - Old Airport Pond
D.D. - Dump Drainage V.P. - Village Pond D.W.S. - Drinking Water Source
B.L. - Big Lake S.L.D - Sewage Lagoon Drainage S.L. - Sewage Lagoon

Table 2: Microbial Indicator Organisms Soil Data Fall 2009

Sample ID.	GPS Location	Soil Weight	MPN/100mL		Log Mean MPN/100mL	
		(g)	EC	ENT	EC	ENT
S1	N60^0 12.762' W162^0 01.748'	0.5	6.0	402.8	0.8	2.6
S2	N60^0 12.784' W162^0 01.819'	0.5	0.0	374.4	0.0	2.6
S3	N60^0 12.764' W162^0 01.721'	0.5	4.0	47.0	0.6	1.7
S4	N60^0 12.772' W162^0 01.724'	0.5	4.0	14.0	0.6	1.1
C	N60^0 12.789' W164^0 01.724'	0.5	0.0	57.0	0.0	1.8
C	N60^0 12.789' W164^0 01.724'	0.5	0.0	16.0	0.0	1.2

S1 - Soil Sample at Burnbox S3 - Soil Sample at Dump Pond
S2 - Soil Sample at Sewage Lagoon Unloading Area S4 - Soil Sample between Dump and Sewage Lagoon
C - Soil Sample at Control Sites

Table 3: Microbial Indicator Organisms Water Data Spring 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.	N60^0 12.751' W162^0 01.641'	0.4	7.6	686.7	2419.6	2.8	3.4
D.	N60^0 12.751' W162^0 01.641'	0.4	7.6	727	2419.6	2.9	3.4
D.	N60^0 12.751' W162^0 01.641'	0.4	7.6	686.7	2419.6	2.8	3.4
D.	N60^0 12.751' W162^0 01.641'	0.4	7.6	686.7	2419.6	2.8	3.4
D.D	N60^0 12.736' W162^0 01.563'	0.2	7.3	727	2419.6	2.9	3.4
D.D.	N60^0 12.736' W162^0 01.563'	0.2	7.3	1119.9	2419.6	3.0	3.4
D.D.	N60^0 12.736' W162^0 01.563'	0.2	7.3	980.4	2419.6	3.0	3.4
D.D.	N60^0 12.736' W162^0 01.563'	0.2	7.3	727	2419.6	2.9	3.4
B.L.	N60^0 12.753' W162^0 01.568'	0.2	6.8	0.0	2.0	0.0	0.3
B.L.	N60^0 12.753' W162^0 01.568'	0.2	6.8	0.0	1.0	0.0	0.0
B.L.	N60^0 12.753' W162^0 01.568'	0.2	6.8	1.0	0.0	0.0	0.0
B.L.	N60^0 12.753' W162^0 01.568'	0.2	6.8	0.0	0.0	0.0	0.0
A.L.	N60^0 12.832' W162^0 01.892'	0.4	5.7	51.2	35	1.7	1.5
A.L.	N60^0 12.832' W162^0 01.892'	0.4	5.7	45.4	42	1.7	1.6
A.L.	N60^0 12.832' W162^0 01.892'	0.4	5.7	49.7	76.3	1.7	1.9
V.P.	N60^0 13.015' W162^0 01.700'	0.6	6.7	4.1	29.3	0.6	1.5
V.P.	N60^0 13.015' W162^0 01.700'	0.6	6.7	2.0	32.7	0.3	1.5
V.P	N60^0 13.015' W162^0 01.700'	0.6	6.7	2.0	33.5	0.3	1.5
E.R.	N60^0 13.197' W162^0 02.086'	0.7	6.3	3.1	13.3	0.5	1.1
E.R.	N60^0 13.197' W162^0 02.086'	0.7	6.3	8.5	0.0	0.9	0.0
E.R.	N60^0 13.197' W162^0 02.086'	0.7	6.3	2.0	2.0	0.3	0.3
O.A.P.	N60^0 12.704' W162^0 00.773'	0.4	5.9	0.0	0.0	0.0	0.0
O.A.P.	N60^0 12.704' W162^0 00.773'	0.4	5.9	0.0	0.0	0.0	0.0
O.A.L.	N60^0 12.704' W162^0 00.773'	0.4	5.9	0.0	0.0	0.0	0.0
D.W.S.		R.T.	7.3	0.0	0.0	0.0	0.0
S.L.	N60^0 12.784' W162^0 01.819'	0.4	6.5	95.8	2419.6	2.0	3.4
S.L.	N60^0 12.784' W162^0 01.819'	0.4	6.5	44.1	2419.6	1.6	3.4

D. - Dump
D.D. - Dump Drainage
B.L. - Big Lake
A.L. - Airport Lake
V.P. - Village Pond
O.A.P. - Old Airport Pond
E.R. - Eek River
D.W.S. - Drinking Water Source
S.L. - Sewage Lagoon

Table 4: Microbial Indicator Organisms Soil Data Spring 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N60^0 12.762' W162^0 01.748'	0.20	77.5	12098.0	1.9	4.1
S1	N60^0 12.762' W162^0 01.748'	0.20	42.5	12098.0	1.6	4.1
S2	N60^0 12.784' W162^0 01.819'	0.20	60.5	6498.5	1.8	3.8
S2	N60^0 12.784' W162^0 01.819'	0.20	0.0	6498.5	0.0	3.8
S2	N60^0 12.784' W162^0 01.819'	0.20	0.0	53.0	0.0	1.7
S2	N60^0 12.784' W162^0 01.819'	0.20	0.0	36.0	0.0	1.6
C	N60^0 12.704' W162^0 00.773'	0.20	0.0	10.0	0.0	1.0

S1 - Soil Sample at Burnbox
S2 - Soil Sample at Sewage Lagoon Unloading Area
C - Soil Sample at Control Site

Table 5: Microbial Indicator Organisms Water Data Fall 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.	N60^0 12.751' W162^0 01.641'	1.8	7.4	6.3	12.1	0.8	1.1
D.	N60^0 12.751' W162^0 01.641'	1.8	7.4	5.2	23.8	0.7	1.4
D.	N60^0 12.751' W162^0 01.641'	1.8	7.4	10.4	15.0	1.0	1.2
D.D	N60^0 12.736' W162^0 01.563'	1.1	7.0	81.3	16.1	1.9	1.2
D.D.	N60^0 12.736' W162^0 01.563'	1.1	7.0	82	21.8	1.9	1.3
D.D.	N60^0 12.736' W162^0 01.563'	1.1	7.0	72.8	26.8	1.9	1.4
B.L.	N60^0 12.753' W162^0 01.568'	2.1	7.3	4.1	4.1	0.6	0.6
B.L.	N60^0 12.753' W162^0 01.568'	2.1	7.3	8.6	3.0	0.9	0.5
B.L.	N60^0 12.753' W162^0 01.568'	2.1	7.3	7.5	7.2	0.9	0.9
A.L.	N60^0 12.832' W162^0 01.892'	2.7	7.4	1.0	64.0	0.0	1.8
A.L.	N60^0 12.832' W162^0 01.892'	2.7	7.4	7.4	28.1	0.9	1.4
A.L.	N60^0 12.832' W162^0 01.892'	2.7	7.4	0.0	76.3	0.0	1.9
V.P.	N60^0 13.015' W162^0 01.700'	1.6	7.5	90.9	2419.6	2.0	3.4
V.P.	N60^0 13.015' W162^0 01.700'	1.6	7.5	74.8	2419.6	1.9	3.4
V.P	N60^0 13.015' W162^0 01.700'	1.6	7.5	133.7	2419.6	2.1	3.4
E.R.	N60^0 10.140' W162^0 01.515'	4.7	7.5	3.0	1.0	0.5	0.0
E.R.	N60^0 10.140' W162^0 01.515'	4.7	7.5	0.0	0.0	0.0	0.0
E.R.	N60^0 10.140' W162^0 01.515'	4.7	7.5	0.0	0.0	0.0	0.0
S.L.	N60^0 12.784' W162^0 01.819'	2.8	8.2	533.5	920.8	2.7	3.0
S.L.	N60^0 12.784' W162^0 01.819'	2.8	8.2	3226.1	426.5	3.5	2.6
S.L.	N60^0 12.784' W162^0 01.819'	2.8	8.2	1921.2	149.6	3.3	2.2
S.L.	N60^0 12.784' W162^0 01.819'	2.8	8.2	1067	66.6	3.0	1.8
D.W.S.		R.T.	7.4	0.0	0.0	0.0	0.0

D. - Dump B.L. - Big Lake O.A.P. - Old Airport Pond
D.D. - Dump Drainage A.L. - Airport Lake D.W.S. - Drinking Water Source
V.P. - Village Pond E.R. - Eek River S.L. - Sewage Lagoon

Table 6: Microbial Indicator Organisms Soil Data Fall 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
C	N60^0 12.762' W162^0 01.748'	0.20	0.0	20.5	0.0	1.3
C	N60^0 12.762' W162^0 01.748'	0.20	0.0	20.5	0.0	1.3
C	N60^0 12.762' W162^0 01.748'	0.20	0.0	25.0	0.0	1.4
S1	N60^0 12.758' W162^0 01.684'	0.20	364.0	12098.0	2.6	4.1
S1	N60^0 12.758' W162^0 01.684'	0.20	1240.5	12098.0	3.1	4.1
S1	N60^0 12.758' W162^0 01.684'	0.20	892.5	12098.0	3.0	4.1
S2	N60^0 12.764' W162^0 01.721'	0.20	10.0	4902.0	1.0	3.7
S2	N60^0 12.764' W162^0 01.721'	0.20	168.5	4902.0	2.2	3.7
S2	N60^0 12.764' W162^0 01.721'	0.20	37.0	1522.0	1.6	3.2
S3	N60^0 12.784' W162^0 01.819'	0.20	1301.5	1490.5	3.1	3.2
S3	N60^0 12.784' W162^0 01.819'	0.20	5599.5	9931.5	3.7	4.0
S3	N60^0 12.784' W162^0 01.819'	0.20	4332.0	9931.5	3.6	4.0

C - Soil Sample at Control Site S2 - Soil Sample between Dump and Sewage Lagoon
S1 - Soil Sample at Dump S3 - Soil Sample at Sewage Lagoon Unloading Area

Table 7: Microbial Indicator Organisms Water Data Spring 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.	N60^0 12.751' W162^0 01.641'	4.5	7.1	325.5	169.1	2.5	2.2
D.	N60^0 12.751' W162^0 01.641'	4.5	7.1	206.4	169.4	2.3	2.2
D.	N60^0 12.751' W162^0 01.641'	4.5	7.1	365.4	161.5	2.6	2.2
D.D	N60^0 12.736' W162^0 01.563'	2.2	6.4	1119.9	135.4	3.0	2.1
D.D.	N60^0 12.736' W162^0 01.563'	2.2	6.4	1299.7	113.7	3.1	2.1
D.D.	N60^0 12.736' W162^0 01.563'	2.2	6.4	816.4	131.4	2.9	2.1
B.L.	N60^0 12.753' W162^0 01.568'	2.3	6.4	16.1	2.0	1.2	0.3
B.L.	N60^0 12.753' W162^0 01.568'	2.3	6.4	10.9	4.1	1.0	0.6
B.L.	N60^0 12.753' W162^0 01.568'	2.3	6.4	13.2	4.1	1.1	0.6
A.L.	N60^0 12.832' W162^0 01.892'	1.6	7.4	0.0	2.0	0.0	0.3
A.L.	N60^0 12.832' W162^0 01.892'	1.6	7.4	0.0	4.1	0.0	0.6
A.L.	N60^0 12.832' W162^0 01.892'	1.6	7.4	0.0	1.0	0.0	0.0
V.P.	N60^0 13.015' W162^0 01.700'	1.8	6.7	31.3	39.7	1.5	1.6
V.P.	N60^0 13.015' W162^0 01.700'	1.8	6.7	14.2	48.1	1.2	1.7
V.P	N60^0 13.015' W162^0 01.700'	1.8	6.7	21.6	48.8	1.3	1.7
V.C.	N60^0 13.197' W162^0 02.086'	1.2	6.2	2.0	11.4	0.3	1.1
V.C.	N60^0 13.197' W162^0 02.086'	1.2	6.2	0.0	0.0	0.0	0.0
V.C.	N60^0 13.197' W162^0 02.086'	1.2	6.2	2.0	1.0	0.3	0.0
O.A.P.	N60^0 12.730' W162^0 00.780'	1.6	6.8	0.0	0.0	0.0	0.0
O.A.P	N60^0 12.730' W162^0 00.780'	1.6	6.8	0.0	0.0	0.0	0.0
O.A.P	N60^0 12.730' W162^0 00.780'	1.6	6.8	0.0	0.0	0.0	0.0
E.R.	N60^0 13.704' W162^0 01.479'	2.9	7.4	0.0	0.0	0.0	0.0
E.R.	N60^0 13.704' W162^0 01.479'	2.9	7.4	1.0	0.0	0.0	0.0
E.R.	N60^0 13.704' W162^0 01.479'	2.9	7.4	0.0	0.0	0.0	0.0
S.L.	N60^0 12.784' W162^0 01.819'	4.6	8.2	33.1	2419.6	1.5	3.4
S.L.	N60^0 12.784' W162^0 01.819'	4.6	8.2	30.3	2419.6	1.5	3.4
S.L.	N60^0 12.784' W162^0 01.819'	4.6	8.2	34.1	2419.6	1.5	3.4
S.L.	N60^0 12.784' W162^0 01.819'	2.8	8.2	1067	66.6	3.0	1.8

D. - Dump
D.D. - Dump Drainage
B.L. - Big Lake
V.C. - Village Creek
A.L. - Airport Lake
V.P. - Village Pond
E.R. - Eek River
O.A.P. - Old Airport Pond
S.L. - Sewage Lagoon

Table 8: Microbial Indicator Organisms Soil Data Spring 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N60^0 12.762' W162^0 01.748'	0.20	37.5	12098.0	1.6	4.1
S1	N60^0 12.762' W162^0 01.748'	0.20	431.0	12098.0	2.6	4.1
S1	N60^0 12.762' W162^0 01.748'	0.20	341.0	3446.5	2.5	3.5
S2	N59^0 21.829' W157^{0}28.797'	0.20	286.5	4569.5	2.5	3.7
S2	N59^0 21.829' W157^{0}28.797'	0.20	5.0	12098.0	0.7	4.1
S2	N59^0 21.829' W157^{0}28.797'	0.20	25.5	8664.5	1.4	3.9
S3	N60^0 12.784' W162^0 01.819'	0.20	15.5	2737.5	1.2	3.4
S3	N60^0 12.784' W162^0 01.819'	0.20	15.5	1627.5	1.2	3.2
S3	N60^0 12.784' W162^0 01.819'	0.20	5.0	863.0	0.7	2.9
C	N60^0 12.704' W162^0 00.773'	0.20	0.0	10.0	0.0	1.0
C	N60^0 12.789' W164^0 01.724'	0.50	0.0	16.0	0.0	1.2

C - Soil Sample at Control Site
S1 - Soil Sample at Burnbox
S2 - Soil Sample between Dump and Sewage Lagoon
S3 - Soil Sample at Sewage Lagoon Unloading Area

Table 9: Microbial Indicator Organisms Water Data Fall 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.	N60^0 12.751' W162^0 01.641'	12	7.3	209.8	64.4	2.3	1.8
D.	N60^0 12.751' W162^0 01.641'	12	7.3	214.2	86	2.3	1.9
D.	N60^0 12.751' W162^0 01.641'	12	7.3	224.7	73.3	2.4	1.9
D.D	N60^0 12.736' W162^0 01.563'	10.1	6.8	21.6	2.0	1.3	0.3
D.D.	N60^0 12.736' W162^0 01.563'	10.1	6.8	23.1	1.0	1.4	0.0
D.D.	N60^0 12.736' W162^0 01.563'	10.1	6.8	18.7	3.0	1.3	0.5
B.L.	N60^0 12.753' W162^0 01.568'	12.9	6.9	3.1	0.0	0.5	0.0
B.L.	N60^0 12.753' W162^0 01.568'	12.9	6.9	1.0	0.0	0.0	0.0
B.L.	N60^0 12.753' W162^0 01.568'	12.9	6.9	1.0	0.0	0.0	0.0
A.L.	N60^0 12.832' W162^0 01.892'	13.9	7.7	0.0	3.1	0.0	0.5
A.L.	N60^0 12.832' W162^0 01.892'	13.9	7.7	0.0	2.0	0.0	0.3
A.L.	N60^0 12.832' W162^0 01.892'	13.9	7.7	0.0	3.0	0.0	0.5
V.P.	N60^0 13.015' W162^0 01.700'	11.3	6.6	1119.9	39.7	3.0	1.6
V.P.	N60^0 13.015' W162^0 01.700'	11.3	6.6	980.4	48.1	3.0	1.7
V.P	N60^0 13.015' W162^0 01.700'	11.3	6.6	686.7	48.8	2.8	1.7
V.C.	N60^0 13.197' W162^0 02.086'	1.2	6.2	2.0	11.4	0.3	1.1
V.C.	N60^0 13.197' W162^0 02.086'	1.2	6.2	0.0	0.0	0.0	0.0
V.C.	N60^0 13.197' W162^0 02.086'	1.2	6.2	0.0	1.0	0.0	0.0
E.R.	N60^0 13.704' W162^0 01.479'	13	7.0	23.1	2.0	1.4	0.3
E.R.	N60^0 13.704' W162^0 01.479'	13	7.0	18.7	0.0	1.3	0.0
E.R.	N60^0 13.704' W162^0 01.479'	13	7.0	13.2	3.0	1.1	0.5
S.L.	N60^0 12.784' W162^0 01.819'	12.8	6.5	33.1	2419.6	1.5	3.4
S.L.	N60^0 12.784' W162^0 01.819'	12.8	6.5	30.3	2419.6	1.5	3.4
S.L.	N60^0 12.784' W162^0 01.819'	12.8	6.5	34.1	2419.6	1.5	3.4

D. - Dump V.C. - Village Creek E.R. - Eek River
A.L. - Airport Lake D.D. - Dump Drainage S.L. - Sewage Lagoon
V.P. - Village Pond B.L. - Big Lake

Table 10: Microbial Indicator Organisms Soil Data Fall 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N60^0 12.762' W162^0 01.748'	0.20	42.5	518.0	1.6	2.7
S1	N60^0 12.762' W162^0 01.748'	0.20	49.0	238.0	1.7	2.4
S1	N60^0 12.762' W162^0 01.748'	0.20	182.0	138.5	2.3	2.1
S2	N59^0 21.829' W157^{0}28.797'	0.20	0.0	55.5	0.0	1.7
S2	N59^0 21.829' W157^{0}28.797'	0.20	0.0	88.0	0.0	1.9
S2	N59^0 21.829' W157^{0}28.797'	0.20	15.0	97.5	1.2	2.0
S3	N60^0 12.784' W162^0 01.819'	0.20	0.0	46.0	0.0	1.7
S3	N60^0 12.784' W162^0 01.819'	0.20	0.0	25.0	0.0	1.4
S3	N60^0 12.784' W162^0 01.819'	0.20	5.0	50.5	0.7	1.7
C	N60^0 12.704' W162^0 00.773'	0.20	0.0	5.0	0.0	0.7
C	N60^0 12.789' W164^0 01.724'	0.50	0.0	16.0	0.0	1.2

C - Soil Sample at Control Site S2 - Soil Sample between Dump and Sewage Lagoon
S1 - Soil Sample at Burnbox S3 - Soil Sample at Sewage Lagoon Unloading Area

Appendix D-iii: Microbial Indicator Organism Data for Ekwok

Table 1: Microbial Indicator Organisms Water Data Spring 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.1	N59^0 21.741' W157^0 28.423'	1.2	6.6	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.741' W157^0 28.423'	1.2	6.6	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.741' W157^0 28.423'	1.2	6.6	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.741' W157^0 28.423'	1.2	6.6	2419.6	2419.6	3.4	3.4
D.#3	N59^0 21.738' W157^0 28.423'	1.9	6.8	2419.6	183.3	3.4	2.3
D.#3	N59^0 21.738' W157^0 28.423'	1.9	6.8	1119.9	107.9	3.0	2.0
D.#3	N59^0 21.738' W157^0 28.423'	1.9	6.8	1986.3	84.9	3.3	1.9
D.#3	N59^0 21.738' W157^0 28.423'	1.9	6.8	2419.6	60.9	3.4	1.8
D.2	N59^0 21.714' W157^0 28.416'	9.3	6.4	2419.6	2419.6	3.4	3.4
D.2	N59^0 21.714' W157^0 28.416'	9.3	6.4	2419.6	2419.6	3.4	3.4
D.2	N59^0 21.714' W157^0 28.416'	9.3	6.4	2419.6	2419.6	3.4	3.4
D.2	N59^0 21.714' W157^0 28.416'	9.3	6.4	1986.3	2419.6	3.3	3.4
K.C.	N59^0 21.792' W157^0 28.859'	2.9	6.2	3.1	2.0	0.5	0.3
K.C.	N59^0 21.792' W157^0 28.859'	2.9	6.2	5.2	0.0	0.7	0.0
K.C.	N59^0 21.792' W157^0 28.859'	2.9	6.2	3.1	2.0	0.5	0.3
D.3	N59^0 21.711' W157^0 28.440'	9.3	6.9	12.1	51.2	1.1	1.7
D.3	N59^0 21.711' W157^0 28.440'	9.3	6.9	14.5	29.5	1.2	1.5
D.3	N59^0 21.711' W157^0 28.440'	9.3	6.9	21.3	34.1	1.3	1.5
D.4	N59^0 21.325' W157^0 28.792'	9.2	6.1	7.4	93.4	0.9	2.0
D.4	N59^0 21.325' W157^0 28.792'	9.2	6.1	7.5	98.5	0.9	2.0
D.4	N59^0 21.325' W157^0 28.792'	9.2	6.1	7.5	69.5	0.9	1.8
G.P.	N59^0 21.325' W157^0 28.792'	6.9	7.1	9.7	178.5	1.0	2.3
G.P.	N59^0 21.325' W157^0 28.792'	6.9	7.1	9.6	260.3	1.0	2.4
D.W.S.		R.T.	7.2	0.0	0.0	0.0	0.0
D.W.S.		R.T.	7.2	0.0	0.0	0.0	0.0
D.W.S.		R.T.	7.2	0.0	0.0	0.0	0.0

D.1 - Runoff Water at Dump
K.C. - Klutuk Creek
D.#3 -Surface Water at EKPZ-03
G.P. - Gravel Pit
D.2. - Surface Water at New Dump Trench
D.3 - Surface Water at newly decomposed Waste
D.4 - Surface Water at decomposed Waste
D.W.S. - Drinking Water Source

Table 2: Microbial Indicator Organisms Soil Data Spring 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N59^0 21.325' W157^0 28.792'	0.20	5.0	310.0	0.7	2.5
S2	N59^0 21.704' W157^0 28.433'	0.20	278.5	929.0	2.4	3.0
S3	N59^0 21.714' W157^0 28.416'	0.20	182.0	611.0	2.3	2.8
C	N59^0 21.782' W157^0 28.708'	0.20	0.0	10.0	0.0	1.0

C - Soil Sample at Control Site
S2 - Soil Sample at Newly Decomposed Waste
S1 - Soil Sample at Decomposed Waste
S3 - Soil Sample at Dump Trench

Table 3: Microbial Indicator Organisms Water Data Fall 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
K.C.	N59^0 21.798' W157^0 28.832'	4.7	6.2	0.0	1.0	0.0	0.0
K.C.	N59^0 21.798' W157^0 28.832'	4.7	6.2	0.0	2.0	0.0	0.3
K.C.	N59^0 21.798' W157^0 28.832'	4.7	6.2	0.0	5.2	0.0	0.7
N.R.	N59^0 16.102' W162^0 51.082'	5.3	7.3	49.0	2419.6	1.7	3.4
N.R.	N59^0 16.102' W162^0 51.082'	5.3	7.3	26.9	183.3	1.4	2.3
N.R.	N59^0 16.102' W162^0 51.082'	5.3	7.3	28.7	2419.6	1.5	3.4
D.1	N59^0 21.716' W157^0 28.832'	6.8	7.0	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.716' W157^0 28.832'	6.8	7.0	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.716' W157^0 28.832'	6.8	7.0	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.838' W157^0 29.034'	8.4	8.4	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.838' W157^0 29.034'	8.4	8.4	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.838' W157^0 29.034'	8.4	8.4	4839.36	4839.2	3.7	3.7
S.L.	N59^0 20.838' W157^0 29.034'	8.4	8.4	4839.36	4839.2	3.7	3.7
S.L.	N59^0 20.838' W157^0 29.034'	8.4	8.4	4839.36	4839.2	3.7	3.7
O.D.	N59^0 21.396' W157^0 28.621'	8.7	6.3	33.3	206.2	1.5	2.3
O.D.	N59^0 21.396' W157^0 28.621'	8.7	6.3	37.2	2419.6	1.6	3.4
O.D.	N59^0 21.396' W157^0 28.621'	8.7	6.3	70.3	196.8	1.8	2.3
G.P.	N59^0 21.277' W157^0 29.031'	5.8	7.2	87.5	211	1.9	2.3
G.P.	N59^0 21.277' W157^0 29.031'	5.8	7.2	12.1	51.2	1.1	1.7
G.P.	N59^0 21.277' W157^0 29.031'	5.8	7.2	14.5	29.5	1.2	1.5
D.W.S.		R.T.	7.6	0.0	0.0	0.0	0.0

D.1 - Surface Water at Dump
K.C. - Klutuk Creek
N.R. - Nushagak River
D.W.S. - Drinking Water Source
S.L. Sewage Lagoon
O.D. - Surface Water at Old Dump
G.P. - Gravel Pit

Table 4: Microbial Indicator Organisms Soil Data Fall 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N59^0 21.699' W157^0 28.403'	0.20	212.5	214.0	2.3	2.3
S1	N59^0 21.699' W157^0 28.403'	0.20	0.0	69.0	0.0	1.8
S1	N59^0 21.699' W157^0 28.403'	0.20	15.5	343.0	1.2	2.5
S2	N59^0 21.699' W157^0 28.409'	0.20	0.0	5.0	0.0	0.7
S2	N59^0 21.699' W157^0 28.409'	0.20	0.0	5.0	0.0	0.7
S2	N59^0 21.699' W157^0 28.409'	0.20	0.0	10.0	0.0	1.0
S3	N59^0 21.699' W157^0 28.416'	0.20	0.0	10.0	0.0	1.0
S3	N59^0 21.699' W157^0 28.416'	0.20	0.0	20.0	0.0	1.3
S3	N59^0 21.699' W157^0 28.416'	0.20	0.0	10.0	0.0	1.0
S4	N59^0 21.703' W157^0 28.442'	0.20	0.0	51.0	0.0	1.7
S4	N59^0 21.703' W157^0 28.442'	0.20	0.0	57.5	0.0	1.8
S4	N59^0 21.703' W157^0 28.442'	0.20	5.0	40.5	0.7	1.6
S5	N59^0 21.718' W157^0 28.434'	0.20	0.0	77.0	0.0	1.9
S5	N59^0 21.718' W157^0 28.434'	0.20	0.0	53.5	0.0	1.7
S5	N59^0 21.718' W157^0 28.434'	0.20	0.0	40.5	0.0	1.6
C	N59^0 21.717' W157^0 28.422'	0.20	0.0	20.0	0.0	1.3
C	N59^0 21.717' W157^0 28.422'	0.20	0.0	10.0	0.0	1.0
C	N59^0 21.717' W157^0 28.422'	0.20	0.0	25.0	0.0	1.4

C - Soil Sample at Control Site
S1 - Soil Sample at Burnbox
S2 - Soil Sample at Newly Decomposed Waste
S3 - Soil Sample at Decomposed and Covered Waste
S4 - Soil Sample at Dump Trench
S5 - Soil Sample at Decomposed Waste

Table 5: Microbial Indicator Organisms Soil Data Spring 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL EC	MPN/100mL ENT	Log Mean MPN/100mL EC	Log Mean MPN/100mL ENT
S1	N59^0 21.719' W157^0 28.423'	0.20	275.0	12098.0	2.4	4.1
S1	N59^0 21.719' W157^0 28.423'	0.20	175.0	156.5	2.2	2.2
S1	N59^0 21.719' W157^0 28.423'	0.20	202.5	4902.0	2.3	3.7
S2	N59^0 21.714' W157^0 28.392'	0.20	31.5	12098.0	1.5	4.1
S2	N59^0 21.714' W157^0 28.392'	0.20	31.5	12098.0	1.5	4.1
S2	N59^0 21.714' W157^0 28.392'	0.20	26.0	2858.5	1.4	3.5
S3	N59^0 21.708' W157^0 28.428'	0.20	12098.0	62.0	4.1	1.8
S3	N59^0 21.708' W157^0 28.428'	0.20	12098.0	167.0	4.1	2.2
S3	N59^0 21.708' W157^0 28.428'	0.20	12098.0	74.5	4.1	1.9
C	N59^0 21.782' W157^0 28.708'	0.20	0.0	40.5	0.0	1.6
C	N59^0 21.782' W157^0 28.708'	0.20	0.0	60.0	0.0	1.8

C - Soil Sample at Control Site
S1 - Soil Sample at Decomposed Waste
S3 - Soil Sample at Burnbox
S2 - Soil Sample at Dump Trench

Table 6: Microbial Indicator Organisms Water Data Spring 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL EC	MPN/100mL ENT	Log Mean MPN/100mL EC	Log Mean MPN/100mL ENT
D.#3	N59^0 21.739' W157^0 28.431'	6.8	7.4	2419.6	2419.6	3.4	3.4
D.#3	N59^0 21.739' W157^0 28.431'	6.8	7.4	1119.9	2419.6	3.0	3.4
D.#3	N59^0 21.739' W157^0 28.431'	6.8	7.4	1986.3	2419.6	3.3	3.4
D.1	N59^0 21.702' W157^0 28.429'	11.0	6.7	0.0	1.0	0.0	0.0
D.1	N59^0 21.702' W157^0 28.429'	11.0	6.7	0.0	0.0	0.0	0.0
D.1	N59^0 21.702' W157^0 28.429'	11.0	6.7	0.0	0.0	0.0	0.0
K.C.	N59^0 21.800' W157^0 28.827'	3.4	7.6	18.9	0.0	1.3	0.0
K.C.	N59^0 21.800' W157^0 28.827'	3.4	7.6	13.4	0.0	1.1	0.0
K.C.	N59^0 21.800' W157^0 28.827'	3.4	7.6	13.2	0.0	1.1	0.0
N.R.	N59^0 20.785' W157^0 28.729'	1.1	7.8	78.5	2.0	1.9	0.3
N.R.	N59^0 20.785' W157^0 28.729'	1.1	7.8	107.6	2.0	2.0	0.3
N.R.	N59^0 20.785' W157^0 28.729'	1.1	7.8	71.7	0.0	1.9	0.0
S.L.	N59^0 20.845' W157^0 29.024'	0.6	7.4	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.845' W157^0 29.024'	0.6	7.4	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.845' W157^0 29.024'	0.6	7.4	2419.6	2419.6	3.4	3.4
D.2	N59^0 21.708' W157^0 28.433'	12.9	7.2	488.4	2419.6	2.7	3.4
D.2	N59^0 21.708' W157^0 28.433'	12.9	7.2	410.6	2419.6	2.6	3.4
D.2	N59^0 21.708' W157^0 28.433'	12.9	7.2	307.6	2419.6	2.5	3.4
D.3	N59^0 21.711' W157^0 28.453'	3.5	6.3	0.0	3.1	0.0	0.5
D.3	N59^0 21.711' W157^0 28.453'	3.5	6.3	0.0	8.6	0.0	0.9
D.3	N59^0 21.711' W157^0 28.453'	3.5	6.3	0.0	2.0	0.0	0.3
O.D.	N59^0 21.800' W157^0 28.827'	9.2	7.5	0.0	0.0	0.0	0.0
O.D.	N59^0 21.800' W157^0 28.827'	9.2	7.5	0.0	2.0	0.0	0.3
O.D.	N59^0 21.800' W157^0 28.827'	9.2	7.5	0.0	20.2	0.0	1.3
D.W.S.		R.T.		0.0	0.0	0.0	0.0
D.W.S.		R.T.		0.0	0.0	0.0	0.0
D.W.S.		R.T.		0.0	0.0	0.0	0.0

S.L. Sewage Lagoon
D.#3 -Surface Water at EKPZ-03
D.1. - Surface Water at New Dump Trench
K.C. - Klutuk Creek
N.R. - Nushagak River
D.W.S. - Drinking Water Source
D.2 - Surface Water at newly decomposed Waste
D.3 - Surface Water at decomposed Waste
O.D. - Surface Water at Old Dump

Table 7: Microbial Indicator Organisms Water Data Fall 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.1	N59^0 21.717' W157^0 28.396'	18.8	6.8	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.717' W157^0 28.396'	18.8	6.8	2419.6	2419.6	3.4	3.4
D.1	N59^0 21.717' W157^0 28.396'	18.8	6.8	2419.6	2419.6	3.4	3.4
N.R.	N59^0 20.785' W157^0 28.729'	11.1	7.4	28.5	5.0	1.5	0.7
N.R.	N59^0 20.785' W157^0 28.729'	11.1	7.4	14.2	3.0	1.2	0.5
N.R.	N59^0 20.785' W157^0 28.729'	11.1	7.4	24.6	2.0	1.4	0.3
S.L.	N59^0 20.845' W157^0 29.024'	11.4	7.8	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.845' W157^0 29.024'	11.4	7.8	2419.6	2419.6	3.4	3.4
S.L.	N59^0 20.845' W157^0 29.024'	11.4	7.8	2419.6	2419.6	3.4	3.4
D.3	N59^0 21.689' W157^0 28.366'	19.5	7.7	2419.6	2419.6	3.4	3.4
D.3	N59^0 21.689' W157^0 28.366'	19.5	7.7	2419.6	2419.6	3.4	3.4
D.3	N59^0 21.689' W157^0 28.366'	19.5	7.7	2419.6	2419.6	3.4	3.4
O.D.	N59^0 21.800' W157^0 28.827'	11.3	7.0	1.0	11.2	0.0	1.0
O.D.	N59^0 21.800' W157^0 28.827'	11.3	7.0	1.0	10.2	0.0	1.0
O.D.	N59^0 21.800' W157^0 28.827'	11.3	7.0	1.0	9.5	0.0	1.0

S.L. - Sewage Lagoon D.3 - Surface Water at decomposed Waste N.R. - Nushagak River
D.1. - Surface Water at New Dump Trench O.D. - Surface Water at Old Dump

Table 8: Microbial Indicator Organisms Soil Data Fall 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N59^0 21.719' W157^0 28.423'	0.20	0.0	71.0	0.0	1.9
S1	N59^0 21.719' W157^0 28.423'	0.20	0.0	15.0	0.0	1.2
S1	N59^0 21.719' W157^0 28.423'	0.20	0.0	70.5	0.0	1.8
S2	N59^0 21.714' W157^0 28.392'	0.20	67.0	579.5	1.8	2.8
S2	N59^0 21.714' W157^0 28.392'	0.20	677.0	1584.5	2.8	3.2
S2	N59^0 21.714' W157^0 28.392'	0.20	25.5	1892.0	1.4	3.3
S3	N59^0 21.708' W157^0 28.428'	0.20	48.0	553.5	1.7	2.7
S3	N59^0 21.708' W157^0 28.428'	0.20	587.0	187.5	2.8	2.3
S3	N59^0 21.708' W157^0 28.428'	0.20	369.0	235.5	2.6	2.4
C	N59^0 21.782' W157^0 28.708'	0.20	0.0	10.0	0.0	1.0
C	N59^0 21.782' W157^0 28.708'	0.20	0.0	15.0	0.0	1.2

C - Soil Sample at Control Site S3 - Soil Sample at Burnbox
S1 - Soil Sample at Decomposed Waste S2 - Soil Sample at Dump Trench

Appendix D-iv: Microbial Indicator Organism Data for Fort Yukon

Table 1: Microbial Indicator Organisms Water Data Summer 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.1	N66^0 34.929' W145^0 13.125'	12.9	7.2	0.0	5.1	0.0	0.7
D.1	N66^0 34.929' W145^0 13.125'	12.9	7.2	0.0	2.0	0.0	0.3
D.1	N66^0 34.929' W145^0 13.125'	12.9	7.2	2.0	3.0	0.3	0.5
D.1	N66^0 34.929' W145^0 13.125'	12.9	7.27	2.0	4.0	0.3	0.6
D.1	N66^0 34.929' W145^0 13.125'	12.9	7.27	4.0	6.0	0.6	0.8
D.#1	N66^0 34.934' W145^0 13.094'	9.8	7.27	54.5	16.0	1.7	1.2
D.#1	N66^0 34.934' W145^0 13.094'	9.8	7.27	9.4	11.3	1.0	1.1
D.#1	N66^0 34.934' W145^0 13.094'	9.8	7.26	21.8	42.8	1.3	1.6
D.#1	N66^0 34.934' W145^0 13.094'	9.8	7.26	16.6	18.2	1.2	1.3
D.#1	N66^0 34.934' W145^0 13.094'	9.8	7.26	12.6	4.0	1.1	0.6
Y.R.	N66^0 34.105' W145^0 17.062'	17.7	7.85	3.1	1.0	0.5	0.0
Y.R.	N66^0 34.105' W145^0 17.062'	17.7	7.85	1.0	0.0	0.0	0.0
Y.R.	N66^0 34.105' W145^0 17.062'	17.7	7.85	0.0	0.0	0.0	0.0
P.R.	N66^0 35.595' W145^0 13.368'	18.9	7.85	33.1	10.9	1.5	1.0
P.R.	N66^0 35.595' W145^0 13.368'	18.9	7.85	19.9	8.6	1.3	0.9
P.R.	N66^0 35.595' W145^0 13.368'	18.9	7.85	21.8	5.2	1.3	0.7
H.L.	N66^0 34.300' W145^0 15.165'	21.3	8.55	4.1	4.1	0.6	0.6
H.L.	N66^0 34.300' W145^0 15.165'	21.3	8.55	0.0	4.1	0.0	0.6
H.L.	N66^0 34.300' W145^0 15.165'	21.3	8.55	0.0	6.2	0.0	0.8
Y.R.S.	N66^0 34.331' W145^0 17.112'	16.8	6.79	4.1	79.8	0.6	1.9
Y.R.S.	N66^0 34.331' W145^0 17.112'	16.8	6.79	4.1	62.7	0.6	1.8
Y.R.S.	N66^0 34.331' W145^0 17.112'	16.8	6.79	4.1	64.5	0.6	1.8
Y.R.S.	N66^0 34.331' W145^0 17.112'	16.8	6.79	4.0	48.2	0.6	1.7
Y.R.S.	N66^0 34.331' W145^0 17.112'	16.8	6.79	6.2	159.6	0.8	2.2
Y.R.S.	N66^0 34.331' W145^0 17.112'	16.8	6.79	2.0	129	0.3	2.1
S.L.	N66^0 34.113' W145^0 10.843'	23.3	8.4	11.2	1.0	1.0	0.0
S.L.	N66^0 34.113' W145^0 10.843'	23.3	8.4	4.1	1.0	0.6	0.0
S.L.	N66^0 34.113' W145^0 10.843'	23.3	8.4	2.0	0.0	0.3	0.0
D.W.S.		R.T.	7.4	0.0	0.0	0.0	0.0

D.1 - Standing Water at Dump Drainage
D.#1 -Surface Water at FYPZ-01
Y.R. - Yukon River
P.R. - Porcupine River
H.L. - Hospital Lake
Y.R.S. - Slough access Yukon River
S.L. - Sewage Lagoon
D.W.S. - Drinking Water Source

Table 2: Microbial Indicator Organisms Soil Data Summer 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL EC	MPN/100mL ENT	Log Mean MPN/100mL EC	Log Mean MPN/100mL ENT
S1	N66^0 34.935' W145^0 18.117'	0.22	139.5	5469.5	2.1	3.7
S1	N66^0 34.935' W145^0 18.117'	0.22	139.5	10998.2	2.1	4.0
S1	N66^0 34.935' W145^0 18.117'	0.24	139.5	9030.0	2.1	4.0
S2	N66^0 34.936' W145^0 13.094'	0.22	9.1	1986.8	1.0	3.3
S2	N66^0 34.936' W145^0 13.094'	0.24	0.0	393.6	0.0	2.6
S2	N66^0 34.936' W145^0 13.094'	0.22	0.0	1170.5	0.0	3.1
S2	N66^0 34.936' W145^0 13.094'	0.22	1315.5	584.5	3.1	2.8
S2	N66^0 34.936' W145^0 13.094'	0.20	537.3	263.2	2.7	2.4
S2	N66^0 34.936' W145^0 13.094'	0.23	7059.5	10998.2	3.8	4.0
S3	N66^0 34.914' W145^0 12.995'	0.27	9.1	73.6	0.0	0.0
S3	N66^0 34.914' W145^0 12.995'	0.24	9.1	79.1	0.0	0.0
S3	N66^0 34.914' W145^0 12.995'	0.27	9.1	89.5	0.0	0.0
S4	N66^0 34.936' W145^0 12.996'	0.25	9.1	50.0	1.0	1.9
S4	N66^0 34.936' W145^0 12.996'	0.25	9.1	68.6	1.0	1.9
S4	N66^0 34.936' W145^0 12.996'	0.21	0.0	40.9	1.0	2.0
C	N66^0 34.900' W145^0 13.025'	0.23	0.0	60.5	1.0	1.7
C	N66^0 34.900' W145^0 13.025'	0.22	0.0	89.5	1.0	1.8
C	N66^0 34.900' W145^0 13.025'	0.22	0.0	128.6	0.0	2.1
C	N66^0 34.869' W145^0 12.926'	0.25	0.0	151.4	0.0	2.2
C	N66^0 34.869' W145^0 12.926'	0.22	0.0	216.8	0.0	2.3
C	N66^0 34.869' W145^0 12.926'	0.23	0.0	177.7	0.0	2.2

C - Soil Sample at Control Site
S1 - Soil Sample at FY-PZ-01
S2 - Soil Sample at Dump Drainage
S3 - Soil Sample at Newly Disposed Waste
S4 - Soil Sample at Burned Waste

Table 3: Microbial Indicator Organisms Soil Data Spring 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL EC	MPN/100mL ENT	Log Mean MPN/100mL EC	Log Mean MPN/100mL ENT
S1	N66^0 34.871' W145^0 12.962'	0.20	1190.5	12098.0	3.1	4.1
S1	N66^0 34.871' W145^0 12.962'	0.20	533.0	12098.0	2.7	4.1
S1	N66^0 34.871' W145^0 12.962'	0.20	694.0	98.5	2.8	2.0
S2	N66^0 34.892' W145^0 13.117'	0.60	3.3	46.2	0.5	1.7
S2	N66^0 34.892' W145^0 13.117'	0.60	5.0	30.8	0.7	1.5
S2	N66^0 34.892' W145^0 13.117'	0.60	0.0	34.2	0.0	1.5
S3	N66^0 34.880' W145^0 13.016'	0.20	2752.0	12098.0	3.4	4.1
S3	N66^0 34.880' W145^0 13.016'	0.20	1939.5	12098.0	3.3	4.1
S3	N66^0 34.880' W145^0 13.016'	0.20	3202.5	12098.0	3.5	4.1
C	N66^0 34.887' W145^0 12.959'	0.20	35.0	284.0	1.5	2.5
C	N66^0 34.887' W145^0 12.959'	0.20	40.0	222.5	1.6	2.3
C	N66^0 34.887' W145^0 12.959'	0.20	10.0	175.0	1.0	2.2

C - Soil Sample at Control Site
S1 - Soil Sample at Newly Disposed Waste
S2 - Soil Sample at FYPZ-04
S3 - Soil Sample at Burned Waste

Table 4: Microbial Indicator Organisms Water Data Spring 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.1	N66^{0}34.929' W145^0 13.125'	4.7	7.7	43.1	2419.6	1.6	3.4
D.1	N66^{0}34.929' W145^0 13.125'	4.7	7.7	51.2	2419.6	1.7	3.4
D.1	N66^{0}34.929' W145^0 13.125'	4.7	7.7	25.9	2419.6	1.4	3.4
D.#2	N66^{0}34.890' W145^0 12.991'	5.6	8.4	343.3	2419.6	2.5	3.4
D.#2	N66^{0}34.890' W145^0 12.991'	5.6	8.4	68.3	2419.6	1.8	3.4
D.#2	N66^{0}34.890' W145^0 12.991'	5.6	8.4	80.1	2419.6	1.9	3.4
D.#1	N66^{0}34.934' W145^0 13.094'	14	7.9	7.4	9.5	0.9	1.0
D.#1	N66^{0}34.934' W145^0 13.094'	14	7.9	12.1	4.1	1.1	0.6
D.#1	N66^{0}34.934' W145^0 13.094'	14	7.9	12	2.0	1.1	0.3
D.#3	N66^{0}34.934' W145^0 13.094'	15.5	7.2	7.4	36.4	0.9	1.6
D.#3	N66^{0}34.892' W145^0 13.117'	15.5	7.2	12.1	123.4	1.1	2.1
D.#3	N66^{0}34.892' W145^0 13.117'	15.5	7.2	12.0	176	1.1	2.2
D.#4	N66^{0}34.892' W145^0 13.117'	21.5	8.6	2.0	4.1	0.3	0.6
D.#4	N66^{0}34.892' W145^0 13.117'	21.5	8.6	1.3	10.8	0.1	1.0
D.#4	N66^{0}34.742' W145^0 14.784'	21.5	8.6	1.3	9.4	0.1	1.0
Y.R.	N66^{0}34.742' W145^0 14.784'	13	8.4	8.5	0.0	0.9	0.0
Y.R.	N66^{0}34.742' W145^0 14.784'	13	8.4	8.4	3.0	0.9	0.5
Y.R.	N66^{0}34.882' W145^0 13.008'	13	8.4	10.9	4.1	1.0	0.6
H.L.	N66^{0}34.882' W145^0 13.008'	12.8	8.3	4.0	12.8	0.6	1.1
H.L.	N66^{0}34.882' W145^0 13.008'	12.8	8.3	5.2	20.0	0.7	1.3
H.L.	N66^{0}34.322' W145^0 17.260'	12.8	8.3	4.1	27.2	0.6	1.4
Y.R.S.	N66^{0}34.322' W145^0 17.260'	14.2	8.4	3.1	7.2	0.5	0.9
Y.R.S.	N66^{0}34.322' W145^0 17.260'	14.2	8.4	2.0	4.1	0.3	0.6
Y.R.S.	N66^{0}34.900' W145^0 13.025'	14.2	8.4	5.2	13.4	0.7	1.1
S.L.	N66^{0}34.900' W145^0 13.025'	16.9	8.1	3.1	3.0	0.5	0.5
S.L.	N66^{0}34.900' W145^0 13.025'	16.9	8.1	2.0	3.1	0.3	0.5
S.L.	N66^{0}34.900' W145^0 13.025'	16.9	8.1	1.0	5.2	0.0	0.7

D.1 - Standing Water at Dump Drainage
D.#1 -Surface Water at FYPZ-01
D.#2 -Surface Water at FYPZ-02
D.#3 -Surface Water at FYPZ-03
D.#4 -Surface Water at FYPZ-04
H.L. - Hospital Lake
Y.R.S. - Slough access Yukon River
S.L. - Sewage Lagoon
Y.R. - Yukon River

Table 5: Microbial Indicator Organisms Water Data Fall 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.1	N66^{0}34.929' W145^0 13.125'	7.5	7.9	2688.4	2688.4	3.4	3.4
D.1	N66^{0}34.929' W145^0 13.125'	7.5	7.9	2688.4	2688.4	3.4	3.4
D.1	N66^{0}34.929' W145^0 13.125'	7.5	7.9	2688.4	2688.4	3.4	3.4
D.#2	N66^{0}34.890' W145^0 12.991'	9.5	6.7	0.0	10.0	0.0	1.0
D.#2	N66^{0}34.890' W145^0 12.991'	9.5	6.7	0.0	0.0	0.0	0.0
D.#2	N66^{0}34.890' W145^0 12.991'	9.5	6.7	0.0	0.0	0.0	0.0
D.#1	N66^{0}34.934' W145^0 13.094'	10.2	7.2	0.0	10.0	0.0	1.0
D.#1	N66^{0}34.934' W145^0 13.094'	10.2	7.2	0.0	0.0	0.0	0.0
D.#1	N66^{0}34.934' W145^0 13.094'	10.2	7.2	0.0	0.0	0.0	0.0
D.#3	N66^{0}34.934' W145^0 13.094'	9.8	7.5	0.0	5.0	0.0	0.7
D.#3	N66^{0}34.892' W145^0 13.117'	9.8	7.5	0.0	0.0	0.0	0.0
D.#3	N66^{0}34.892' W145^0 13.117'	9.8	7.5	0.0	3.0	0.0	0.5
D.#4	N66^{0}34.892' W145^0 13.117'	11.4	7.8	0.0	0.0	0.0	0.0
D.#4	N66^{0}34.892' W145^0 13.117'	11.4	7.8	0.0	0.0	0.0	0.0
D.#4	N66^{0}34.742' W145^0 14.784'	11.4	7.8	0.0	2.0	0.0	0.3
Y.R.	N66^{0}34.742' W145^0 14.784'	15.3	8.6	21.6	6.1	1.3	0.8
Y.R.	N66^{0}34.742' W145^0 14.784'	15.3	8.6	23.8	2.0	1.4	0.3
Y.R.	N66^{0}34.882' W145^0 13.008'	15.3	8.6	13.5	2.5	1.1	0.4
H.L.	N66^{0}34.882' W145^0 13.008'	16	8.5	6.3	13.1	0.8	1.1
H.L.	N66^{0}34.882' W145^0 13.008'	16	8.5	5.2	8.3	0.7	0.9
H.L.	N66^{0}34.322' W145^0 17.260'	16	8.5	2.2	15.9	0.3	1.2

D.1 - Standing Water at Dump Drainage
D.#1 -Surface Water at FYPZ-01
D.#2 -Surface Water at FYPZ-02
D.#3 -Surface Water at FYPZ-03
D.#4 -Surface Water at FYPZ-04
H.L. - Hospital Lake
Y.R. - Yukon River

Table 6: Microbial Indicator Organisms Soil Data Fall 2011

Sample ID.	GPS Location	Soil Weight	MPN/100mL		Log Mean MPN/100mL	
		(g)	EC	ENT	EC	ENT
S1	N66^0 34.914' W145^0 12.995'	0.20	30.5	12098.0	1.5	4.1
S1	N66^0 34.914' W145^0 12.995'	0.20	205.5	12098.0	2.3	4.1
S1	N66^0 34.914' W145^0 12.995'	0.20	104.5	98.5	2.0	2.0
S2	N66^0 34.916' W145^0 13.045'	0.60	0.0	218.0	0.0	2.3
S2	N66^0 34.916' W145^0 13.045'	0.60	0.0	119.5	0.0	2.1
S3	N66^0 34.900' W145^0 13.025'	0.20	20.0	12098.5	1.3	4.1
S3	N66^0 34.900' W145^0 13.025'	0.20	5.0	12098.0	0.7	4.1
S3	N66^0 34.900' W145^0 13.025'	0.20	5.0	12098.0	0.7	4.1
C	N66^0 34.887' W145^0 12.959'	0.20	1	11.2	0.0	1.0
C	N66^0 34.887' W145^0 12.959'	0.20	1	10.2	0.0	1.0
C	N66^0 34.887' W145^0 12.959'	0.20	1	9.5	0.0	1.0

C - Soil Sample at Control Site
S1 - Soil Sample at Newly Disposed Waste
S3 - Soil Sample at Burned Waste
S2 - Soil Sample at FYPZ-04

Appendix D-v: Microbial Indicator Organism Data for White Mountain

Table 1: Microbial Indicator Organisms Water Data Spring 2010

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.1	N 64^0 40.600' W163^{0}23.326'	3.2	7.4	2419.6	2419.6	3.4	3.4
D.1	N 64^0 40.600' W163^{0}23.326'	3.2	7.4	2419.6	2419.6	3.4	3.4
D.1	N 64^0 40.600' W163^{0}23.326'	3.2	7.4	2419.6	2419.6	3.4	3.4
D.1	N 64^0 40.600' W163^{0}23.326'	3.2	7.4	2419.6	2419.6	3.4	3.4
D.2	N 64^0 40.629' W163^0 23.352'	9.5	7.5	2419.6	183.3	3.4	2.3
D.2	N 64^0 40.629' W163^0 23.352'	9.5	7.5	1119.9	107.9	3.0	2.0
D.2	N 64^0 40.629' W163^0 23.352'	9.5	7.5	1986.3	84.9	3.3	1.9
D.2	N 64^0 40.629' W163^0 23.352'	9.5	7.5	2419.6	60.9	3.4	1.8
D.3	N 64^0 40.600' W163^0 23.329'	9.3	7.5	2419.6	2419.6	3.4	3.4
D.3	N 64^0 40.600' W163^0 23.329'	9.3	7.5	2419.6	2419.6	3.4	3.4
D.3	N 64^0 40.600' W163^0 23.329'	9.3	7.5	2419.6	2419.6	3.4	3.4
D.3	N 64^0 40.600' W163^0 23.329'	9.3	7.5	1986.3	2419.6	3.3	3.4
D.4	N 64^0 40.653' W163^0 23.358'	10.1	6.5	3.1	2.0	0.5	0.3
D.4	N 64^0 40.653' W163^o 23.358'	10.1	6.5	5.2	0.0	0.7	0.0
D.4	N 64^0 40.653' W163^0 23.358'	10.1	6.5	3.1	2.0	0.5	0.3
D.5	N 64^0 40.588' W163^0 23.289'	3.5	8.6	2419.6	2419.6	3.4	3.4
D.5	N 64^0 40.588' W163^0 23.289'	3.5	8.6	2419.6	2419.6	3.4	3.4
D.5	N 64^0 40.588' W163^0 23.289'	3.5	8.6	2419.6	2419.6	3.4	3.4
D.6	N 64^0 40.625' W163^0 23.350'	3.2	6.7	12.1	51.2	1.1	1.7
D.6	N 64^0 40.625' W163^0 23.350'	3.2	6.7	14.5	29.5	1.2	1.5
D.6	N 64^0 40.625' W163^0 23.350'	3.2	6.7	21.3	34.1	1.3	1.5
V.C.	N 64^0 40.588' W163^{0}23.289'	5.6	8.1	7.4	93.4	0.9	2.0
V.C.	N 64^0 40.588' W163^{0}23.289'	5.6	8.1	7.5	98.5	0.9	2.0
V.C.	N 64^0 40.588' W163^0 23.289'	5.6	8.1	7.5	69.5	0.9	1.8
F.R.	N 64^0 40.588' W163^{0}23.289'	2.3	7.9	9.7	178.5	1.0	2.3
F.R.	N 64^0 40.588' W163^0 23.289'	2.3	7.9	9.6	231	1.0	2.4
D.W.S.		R.T.	7.2	0.0	0.0	0.0	0.0
D.W.S.		R.T.	7.2	0.0	0.0	0.0	0.0

D.1 - Standing Water at Burnbox
D.2 - Standing Water at Mid Dump -Mixed Waste
D.3. - Standing Water at Dump Drainage
D.4. - Standing water at Metal Drums
D.W.S. - Drinking Water Source
V.C. - Village Creek
D.5 - Standing Water at Decomposed Waste
F.R. - Fish River
D.6 - Meltwater at Dump Drainage 2

Table 2: Microbial Indicator Organisms Soil Data Spring 2010

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N 64^0 40.607' W163^0 23.353'	0.20	66.0	3202.5	1.8	3.5
S1	N 64^0 40.607' W163^0 23.353'	0.20	20.0	9931.5	1.3	4.0
S1	N 64^0 40.607' W163^0 23.353'	0.20	423.5	287.0	2.6	2.5
S2	N 64^0 40.628' W163^0 23.357'	0.20	423.5	745.5	2.6	2.9
S2	N 64^0 40.628' W163^0 23.357'	0.20	55995.0	431.5	4.7	2.6
S2	N 64^0 40.628' W163^0 23.357'	0.20	617.0	12098.0	2.8	4.1
S3	N 64^0 40.628' W163^0 23.305'	0.20	12098.0	12098.0	4.1	4.1
S3	N 64^0 40.628' W163^0 23.305'	0.20	12098.0	12098.0	4.1	4.1
S3	N 64^0 40.628' W163^0 23.305'	0.20	12098.0	12098.0	4.1	4.1
S4	N 64^0 40.641' W163^0 23.352'	0.20	20.5	173.0	1.3	2.2
S4	N 64^0 40.641' W163^0 23.352'	0.20	91.5	15.0	2.0	1.2
S4	N 64^0 40.641' W163^0 23.352'	0.20	26.0	57.5	1.4	1.8
S5	N 64^0 40.778' W163^0 23.338'	0.20	10.0	80.5	1.0	1.9
S5	N 64^0 40.778' W163^0 23.338'	0.20	15.5	133.0	1.2	2.1
S5	N 64^0 40.778' W163^0 23.338'	0.20	26.0	108.0	1.4	2.0
C	N 64^0 40.728' W163^0 24.147'	0.20	0.0	81.5	0.0	1.9
C	N 64^0 40.728' W163^0 24.147'	0.20	0.0	53.0	0.0	1.7
C	N 64^0 40.728' W163^0 24.147'	0.20	0.0	42.0	0.0	1.6

C - Soil Sample at Control Site
S3 - Soil Sample at Mid Dump -Mixed Waste
S1 - Soil Sample at Newly Disposed Waste
S4 - Soil Sample at Dump Drainage
S2 - Soil Sample at Burnbox
S5 - Soil Sample at Metal Drums

Table 3: Microbial Indicator Organisms Water Data Spring 2011

Sample ID.	GPS Location	Temperature ^{0}C	pH	MPN/100mL		Log Mean MPN/100mL	
				EC	ENT	EC	ENT
D.6	N 64^0 40.625' W163^0 23.350'	11.5	8.7	2419.6	2419.6	3.4	3.4
D.6	N 64^0 40.625' W163^0 23.350'	11.5	8.7	2419.6	2419.6	3.4	3.4
D.6	N 64^0 40.625' W163^0 23.350'	11.5	8.7	2688.4	2419.6	3.4	3.4
D.2	N 64^0 40.629' W163^0 23.352'	20.7	7.9	816.4	2419.6	2.9	3.4
D.2	N 64^0 40.629' W163^0 23.352'	20.7	7.9	1413.6	1986.3	3.2	3.3
D.2	N 64^0 40.629' W163^0 23.352'	20.7	7.9	1244.3	1925.4	3.1	3.3
D.1	N 64^0 40.600' W163^{0}23.326'	21.6	7.8	1553.1	2419.6	3.2	3.4
D.1	N 64^0 40.600' W163^{0}23.326'	21.6	7.8	1413.6	2419.6	3.2	3.4
D.1	N 64^0 40.600' W163^{0}23.326'	21.6	7.8	1337.0	2688.4	3.1	3.4
D.3	N 64^0 40.600' W163^0 23.329'	14.1	7.7	629.4	2419.6	2.8	3.4
D.3	N 64^0 40.600' W163^0 23.329'	14.1	7.7	234.8	2419.6	2.4	3.4
D.3	N 64^0 40.600' W163^0 23.329'	14.1	7.7	571.7	2688.4	2.8	3.4
D.7	N 64^0 40.632' W163^0 23.454'	12.4	8.2	2.0	5.1	0.3	0.7
D.7	N 64^0 40.632' W163^0 23.454'	12.4	8.2	2.0	7.5	0.3	0.9
D.7	N 64^0 40.632' W163^0 23.454'	12.4	8.2	0.0	3.3	0.0	0.5
D.5	N 64^0 40.588' W163^0 23.289'	6.2	8.1	424.5	2419.6	2.6	3.4
D.5	N 64^0 40.588' W163^0 23.289'	6.2	8.1	533.5	2419.6	2.7	3.4
D.5	N 64^0 40.588' W163^0 23.289'	6.2	8.1	424.5	2688.4	2.6	3.4
D.4	N 64^0 40.653' W163^0 23.358'	19.6	8.2	5.2	35.0	0.7	1.5
D.4	N 64^0 40.653' W163^0 23.358'	19.6	8.2	3.4	21.8	0.5	1.3
D.4	N 64^0 40.653' W163^0 23.358'	19.6	8.2	5.2	29.8	0.7	1.5
F.R.	N 64^0 40.588' W163^{0}23.289'	7.8	7.8	79.1	9.4	1.9	1.0
F.R.	N 64^0 40.588' W163^0 23.289'	7.8	7.8	29.5	21.6	1.5	1.3
F.R.	N 64^0 40.588' W163^0 23.289'	7.8	7.8	26.5	7.3	1.4	0.9

D.1 - Standing Water at Burnbox
D.2 - Standing Water at Mid Dump -Mixed Waste
D.3. - Standing Water at Dump Drainage
D.4. - Standing water at Metal Drums
D.5 - Standing Water at Decomposed Waste
D.6 - Meltwater at Dump Drainage 2
D.7. - Standing water Upgradient from Dump
D.W.S. - Drinking Water Source
F.R. - Fish River

Table 4: Microbial Indicator Organisms Soil Data Spring 2011

Sample ID.	GPS Location	Soil Weight (g)	MPN/100mL		Log Mean MPN/100mL	
			EC	ENT	EC	ENT
S1	N 64^0 40.626' W163^0 23.328'	0.20	0.0	75.5	0.0	1.9
S1	N 64^0 40.626' W163^0 23.328'	0.20	0.0	66.0	0.0	1.8
S1	N 64^0 40.626' W163^0 23.328'	0.20	0.0	76.0	0.0	1.9
S2	N 64^0 40.625' W163^0 23.366'	0.20	125.0	12098.0	2.1	4.1
S2	N 64^0 40.625' W163^0 23.366'	0.20	207.0	12098.0	2.3	4.1
S2	N 64^0 40.625' W163^0 23.366'	0.20	116.5	2442.0	2.1	3.4
S3	N 64^0 40.618' W163^0 23.381'	0.20	1627.5	3850.5	3.2	3.6
S3	N 64^0 40.618' W163^0 23.381'	0.20	430.0	4604.0	2.6	3.7
S3	N 64^0 40.618' W163^0 23.381'	0.20	0.0	42.0	0.0	1.6
S3	N 64^0 40.618' W163^0 23.381'	0.20	80.5	12098.0	1.9	4.1
C	N 64^0 40.632' W163^0 23.454'	0.20	0.0	54.0	0.0	1.7
C	N 64^0 40.632' W163^0 23.454'	0.20	0.0	25.0	0.0	1.4
C	N 64^0 40.632' W163^0 23.454'	0.20	0.0	41.0	0.0	1.6

C - Soil Sample at Control Site
S2 - Soil Sample at Burnbox
S1 - Soil Sample at Decomposed Waste
S3 - Soil Sample at Dump Drainage

Appendix E: Organic Compounds Analysis Data

Appendix E-i: Organic Compounds HPLC-MSMS Instrumentation and Extraction Method Data

Table 1: HPLC-MSMS Instrumentation and Solid Phase Extraction Method Development for Organic Compounds

No.	Compound	LOD (ppb)	LOQ (ppb)	Recovery %	Concentration Levels	
					Minimum	Maximum
1	Sulfamethoxazole	0.04	0.13	69.1	0.22	4.95
2	Trimethoprim	0.05	0.14	75.4	0.52	1.08
3	Carbamazepine	0.05	0.13	89.4	N.D	<LOD
4	Venlafaxine	0.04	0.12	98.3	N.D	N/D
5	Sertraline	0.03	0.09	88.4	N.D	N/D
6	Bupropion	0.03	0.10	90.8	0.23	0.84
7	Ibuprophen	0.04	0.11	84.1	0.33	16.96
8	Acetaminophen	0.03	0.09	87.2	1.21	26.87
9	1,7Dimethylxanthine	0.04	0.12	91.6	2.34	53.71
10	Caffeine	0.04	0.12	97.7	0.24	112.40
11	4&5 Methylbenzotriazole	0.04	0.06		N.D	0.88
12	Benzotriazole	0.04	0.07		N.D	4.08
13	DEP	0.01	0.03		N.D	4.05
14	DEHP	0.01	0.04		N.D	5.51
15	DNOP	0.01	0.04		N.D	2.24
16	DBP	0.01	0.03		N.D	8.04
17	DMP	0.004	0.01		N.D	0.04
18	BBP	0.01	0.03		N.D	1.45

*LC MS/MS methods were developed: for benzotriazole constitutes by Hagedorn et al., 2013, pharmaceutical constitutes Ede 2012 and phthalates constitutes by Ali et al., (in review).

Appendix E-ii: Organic Compounds HPLC-MSMS Analysis Data

Table 2: HPLC-MSMS Average Concentration (ppb) for Pharmaceuticals

	Pharmaceutical Compounds									
Location	**Acetam-inophen**	**Dimethyl-xanthine**	**Trimetho-prim**	**Caffeine**	**Sulfamethox-azole**	**Bupropion**	**Venlafaxine**	**Carbamaze-pine**	**Sertraline**	**Ibuprofen**
Eek										
Control	ND	<LOD	ND	<LOD	ND	ND	ND	ND	ND	ND
Landfill	21.13	26.67	0.54	11.94	3.14	<LOD	ND	ND	ND	7.16
Sewage	23.07	41.73	1.08	9.18	0.67	<LOD	ND	<LOD	ND	5.80
Ekwok										
Control	ND	ND	ND	<LOD	ND	ND	ND	ND	ND	ND
Landfill	<LOD	ND	ND	<LOD	0.53	<LOD	ND	ND	ND	ND
Sewage	11.43	28.93	<LOD	23.47	0.22	<LOD	ND	<LOD	ND	6.13
White Mountain										
Control	ND	ND	ND	<LOD	ND	ND	ND	ND	ND	ND
Dump	ND	26.19	ND	109.59	0.46	<LOD	ND	ND	ND	16.96
>50m Landfill	<LOD	25.69	ND	112.40	0.51	<LOD	ND	ND	ND	10.31
Fort Yukon										
Control	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
>50m Landfill	13.41	ND	ND	<LOD	ND	0.84	ND	ND	ND	4.10
Allakaket										
Control	ND	0.56	ND	<LOD	ND	ND	ND	ND	ND	ND
Landfill	5.20	1.62	ND	4.80	<LOD	0.23	ND	ND	ND	0.75
>50m Landfill	0.25	0.65	ND	0.93	<LOD	0.51	ND	ND	ND	ND

Table 3: HPLC-MSMS Average Concentration (ppb) for Benzotrialzoles & Phthalates

Location	4&5 MBT (ppb)	BT (ppb)	DEP (ppb)	DEHP (ppb)	DNOP (ppb)	DBP (ppb)	DMP (ppb)	BBP (ppb)
Eek								
Control	<LOD	0.11	N.D	0.52	0.33	0.33	N.D	0.24
Sewage	0.06	2.03	0.46	0.61	0.29	0.67	N.D	0.11
>50 m Landfill	<LOD	2.92	N.D	0.68	0.44	1.16	N.D	0.20
Landfill	0.07	4.08	N.D	0.69	0.26	1.26	N.D	0.09
Ekwok								
Control	N.D	N.D	0.30	0.62	N.D	0.63	N.D	0.81
Old Landfill	<LOD	0.15	N.D	N.D	N.D	N.D	N.D	N.D
Sewage	0.06	0.78	0.46	0.08	2.24	7.86	0.03	1.11
Landfill	<LOD	0.21	4.81	5.40	N.D	0.68	N.D	0.34
>50 m Landfill	<LOD	0.25	N.D	0.76	<LOD	0.67	N.D	0.20
White Mountain								
>50 m Landfill	<LOD	0.32	N.D	N.D	N.D	N.D	N.D	N.D
Dump	0.17	0.19	0.28	5.38	N.D	2.49	0.03	0.63
Fort Yukon								
>50 m Landfill	<LOD	0.15	N.D	1.60	0.28	1.38	N.D	0.14
Landfill	<LOD	0.48	N.D	2.36	0.27	0.26	N.D	0.14
Control			0.14	0.85	0.28	0.28	<LOD	0.13
Allakaket								
Landfill	0.88	0.29	N.D	1.05	0.59	1.02	0.04	0.53
Control	<LOD	0.11	N.D	N.D	N.D	N.D	N.D	N.D