

Results of caffeine testing in Moose Lake August 2004

Prepared for:
The Moose Lake Water for Life Committee
Bonnyville, Alberta

Prepared by:
Aquality Environmental Consulting Ltd.
11216 – 23B Avenue
Edmonton, Alberta
T6J 4Z6

Jay S. White, M.Sc., P. Biol.

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Executive Summary

In the summer of 2004, the Moose Lake *Water for Life* Committee contracted Aquality Environmental Consulting Ltd. to investigate water quality issues at Moose Lake. Due to the high density of recreational development and permanent housing around Moose Lake, there were fears that faulty septic systems may be contributing to lower water quality. To address this concern, Aquality collected water samples from several sites around Moose Lake on August 12th, 2004. Samples were analyzed for caffeine, an indicator of untreated human sewage.

Caffeine is an ideal indicator for detecting human waste in the natural environment because it has no naturally occurring sources. For this reason, we can assume that any concentrations of caffeine found in surface waters originate from human waste. Humans consume caffeine from a variety of sources including caffeinated beverages, food, analgesics and pharmaceuticals. The average caffeine concentration in the sewage wastes of many countries, including Canada, is 42 µg/L (Buerge et al., 2003), which allow dilutions and loadings to be estimated. Our detection limits were 0.02 µg/L, meaning that our analytic detection levels could detect sewage diluted to 2100 times.

Caffeine was not detected in any of the 10 samples taken from Moose Lake on August 12th, 2004. However, non-detects do not necessarily indicate that untreated human sewage is not present in the tested water. Non-detects can be due to (i) samples were collected too long after a sewage release or flush event (ii) the detection limits of the test were not sensitive enough to detect diluted caffeine levels; or (iii) no caffeine was present in the sewage (i.e. sewage has been partially treated).

This study was undertaken as part of a larger watershed study currently being undertaken by the Moose Lake *Water for Life* group. Terms of Reference for a watershed management plan have recently been approved by Alberta Environment, and this will lead to the development of a watershed management plan for Moose Lake.

Introduction

In the summer of 2004, Aquality Environmental Consulting Ltd. was contracted by the Moose Lake *Water for Life* Committee to investigate concerns over decreasing water quality. One specific concern of the committee was the possibility of human sewage entering Moose Lake from the multitude of cottages and permanent residences located on the shoreline. As the town of Bonnyville draws its drinking water from Moose Lake, the possibility of human sewage in this water supply was deemed to be of utmost importance to identify and eliminate.

Another concern was the random dumping or disposal of untreated sewage into the lake or inflow streams, which is illegal, but difficult to identify, detect and enforce. The *Environmental Enhancement and Protection Act* (EEPA) states that:

“No person shall dispose of waste except:

- a) at a waste management facility, or in a container the content of which will be taken to a waste management facility, that is subject of appropriate approval, registration or notice required under the Act, or
- b) in accordance with written authorization of the Director.”

Aquality Environmental Consulting Ltd. was tasked with developing a sampling protocol to assess the occurrence of human waste in the waters of Moose Lake. The caffeine indicator may be the best tool developed for detection of unauthorized, untreated human sewage disposal. Sites of interest were selected by the Committee for sampling, each one corresponding to a particular development or park adjacent to Moose Lake.

Human waste is undesirable in natural water systems for a variety of health and environmental reasons, particularly when the receiving waters are a drinking water source or used for recreation. Human sewage contains various pathogens and other substances that can be dangerous to human health (EPA, 1994). These include bacteria such as *Escherichia coli* (*E. coli*), parasites such as *Giardia* and *Cryptosporidium* and other non-natural chemical compounds such as pharmaceuticals (Table 1). Pathogens in human fecal waste have the greatest potential to cause infection in other humans, and the failure to appropriately process human sewage poses a great threat to human health (Olson, 2002).

These substances can be harmful to human health by accidental ingestion and through recreational contact (i.e. swimming). Drinking and recreational water quality guidelines have been established for many of these substances that, when followed, minimize the risk to human health. Alberta Environment is responsible under the *Environmental Enhancement and Protection Act* to authorize and require that drinking water is treated by the drinking water supplier to Provincial standards. The Aspen Regional Health Unit is responsible for ensuring the safety of recreational areas (i.e. beaches and popular swimming areas).

Human waste has traditionally been very difficult to detect in aquatic systems, as very few of its components are unique to human waste. For example, fecal coliform bacteria such as *E. coli* has been used by some researchers in the past. However, the presence of coliform bacteria are ambiguous as they are found in all mammalian feces and it is difficult, without using sophisticated DNA-fingerprinting, to identify the exact animal source of this bacteria. A similar problem exists for commonly used antibiotics, which have both human and veterinary uses.

Table 1: Examples of pathogens and related diseases associated with raw human sewage and sewage solids. Table modified from EPA (1992).

Pathogen Class	Examples	Disease
Bacteria	<i>Shigella spp.</i>	Bacillary disease
	<i>Salmonella spp.</i>	Salmonellosis (gastroenteritis)
	<i>Salmonella typhi</i>	Typhoid fever
	<i>Vibrio cholerae</i>	Cholera
	<i>Enteropathogenic-Escherichia coli</i>	A variety of gastroenteric diseases
	<i>Yersinia spp.</i>	Haemolytic Ureic Syndrome
Viruses	<i>Campylobacter jejuni</i>	Yersiniosis (gastroenteritis)
	Hepatitis A Virus	Campylobacteriosis (gastroenteritis)
	Norwalk Virus	Infectious hepatitis
	Rotaviruses	Acute gastroenteritis
	Polioviruses	Acute gastroenteritis
	Coxsackie viruses	Poliomyelitis
	Echoviruses	“Flu-like” symptoms
	Reoviruses	“Flu-like” symptoms
	Astroviruses	Respiratory infections, gastroenteritis
	Calciviruses	Epidemic gastroenteritis
Protozoa	<i>Entamoeba histolytica</i>	Epidemic gastroenteritis
	<i>Giardia lamblia</i>	Amebiasis (amoebic dysentery)
	<i>Cryptosporidium spp.</i>	Giardiasis (gastroenteritis)
	<i>Balantidium coli</i>	Cryptosporidiosis (gastroenteritis)
	<i>Toxoplasma gondii</i>	Balantidiasis (gastroenteritis)
Nematodes (Roundworms)	<i>Ascaris lumbricoides</i>	Toxoplasmosis
	<i>Trichuris trichiura</i>	Digestive and nutritional imbalances, abdominal pain, vomiting, restlessness
	<i>Ascaris suum</i>	Abdominal pain, diarrhea, anemia, weight loss
	<i>Toxocara canis</i>	Symptoms such as coughing, chest pain and fever
	<i>Necator americanus</i>	Fever, abdominal discomfort, muscle aches, neurological symptoms
Cestodes (Tapeworms)	<i>Taenia spp.</i>	Hookworm disease, anemia
	<i>Hymenolepis nana</i>	Nervousness, insomnia, anorexia, abdominal pain, digestive disturbances
		Same as for <i>Taenia sp.</i>

Other potential tracers of human sewage waste, such as nutrients, are also produced naturally in the environment, and are not very effective at specifically detecting human waste.

However, caffeine is an ideal indicator of human sewage, as it is not used in agricultural operations nor is it produced by any native North American plants. Caffeine is excreted by humans in predictable concentrations, which allows for the calculation of approximate dilutions and loadings. Humans consume caffeine from a variety of sources including caffeinated

beverages (coffee, tea, soft drinks), food (chocolate, pastries, desserts), analgesics (cough, cold and headache medicine), and pharmaceuticals (used as a stimulant in cardiac, cerebral and respiratory drugs and as a diuretic). The caffeine indicator test is a novel approach to detecting sewage wastes, and was developed by Aquality Environmental Consulting Ltd. in partnership with the Alberta Research Council.

Methods:

Site Description

Moose Lake is located 240 km northeast of Edmonton near the town of Bonnyville in the boreal mixedwood ecoregion. It is a large, fertile lake which has been valued for its scenic setting and excellent recreational opportunities. The total drainage basin is large (755 km²), or approximately 18.5 times larger than the lake's surface area (40.8 km²) (Mitchell and Prepas, 1990). Eight other lakes are located in the same watershed, they are: Kehewin Lake, Bentley Lake, Chickenhill Lake, Bangs Lake, Thin Lake, Chatwin Lake, Minnie Lake, and Liza Lake (Figure 1). Moose lake has a highly irregular shape, with three distinct basins arranged in a general east-west orientation. Franchere Bay is located on the west end, and contains both the major inflow (the Thin Lake River) and outflow (the Moose Lake River). The maximum depth in Franchere Bay is 15 m. Bonnyville Beach Bay is the largest basin and is located in the middle of Moose Lake, reaching a maximum depth of 12 m. A large island is located in the southwest end of Bonnyville Beach Bay, separating the main bay from a large shallow area. Vezeau Bay is located on the east end of Moose Lake and is the deepest basin, reaching a depth of 18 m. The town of Bonnyville draws its drinking water from the east end of Vezeau Bay.

Agriculture and oil exploration/exploitation are the main activities in the Moose Lake watershed. Recreation and tourism are important activities in the area with Moose Lake hosting a large fishing derby annually. There are four major recreational areas, Moose Lake Provincial Park, Franchere Bay Provincial Recreation Area, Eastbourne Provincial Recreation Area, and Pelican Point Park. Moose Lake is also an important bird staging area hosting a large number of waterfowl, including of Grebes, Pelicans, Terns and Ducks.

The largest population center in the watershed is the town of Bonnyville located just east of Moose Lake. The hamlets of Hosleaw, Franchere, Rife and Beacon Corner and a large portion of the Kehewin First Nations Reserve 123 are also in the watershed. A large portion of the south and east shores of Moose Lake are extensively developed with summer cottages. In the past few decades, new subdivisions have been extensively developed in these areas, with an increasing number of permanent residents in the immediate area around Moose Lake. Most of the watershed is covered with either agricultural land or tree cover. A weir was constructed by the Government of Alberta 6.5 km downstream on the Moose Lake River in 1951 to raise water levels and preserve fish habitat (Mitchell and Prepas, 1990).

Sampling locations

Water samples were collected from ten locations chosen in advance by the *Water for Life* committee, each corresponding with developments or parks located around the lake (Figure 2, Table 2). Locations and corresponding shoreline developments are outlined below.

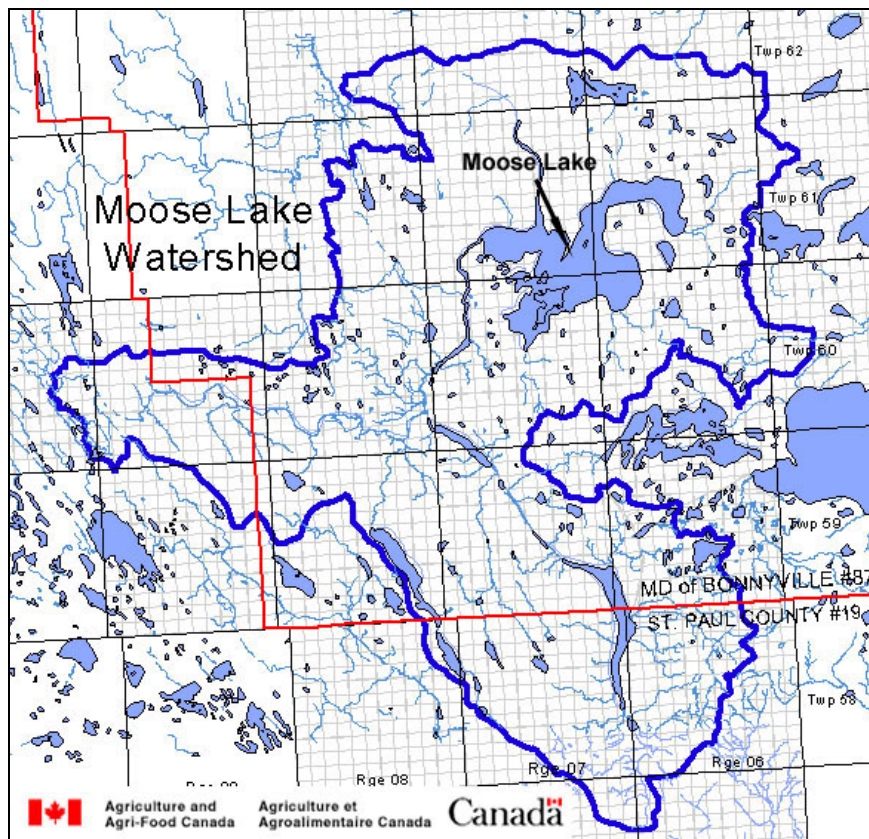


Figure 1: An overview of the Moose Lake watershed. The dark blue line indicates the Moose Lake watershed boundary. Graphic courtesy of Agriculture and Agri-Food Canada, PFRA.

Table 2. Names and GPS coordinates of sampling locations on Moose Lake on August 12th, 2004.

Site	N	W
<i>Vezeau Beach</i>	54 15 250	110 50 001
<i>Turcotte Subdivision</i>	54 16 105	110 50 326
<i>Sunset</i>	54 16 292	110 49 337
<i>North Shore Heights</i>	54 17 055	110 50 115
<i>Pelican Narrows</i>	54 15 400	110 53 545
<i>Model Developments</i>	54 14 547	110 52 305
<i>Bonnyville Beach</i>	54 14 019	110 51 578
<i>Old East Barn</i>	54 13 318	110 55 142
<i>Pentecostal Camp</i>	54 14 582	110 59 275
<i>Franchere Bay Provincial Recreation Area</i>	54 15 249	111 00 077

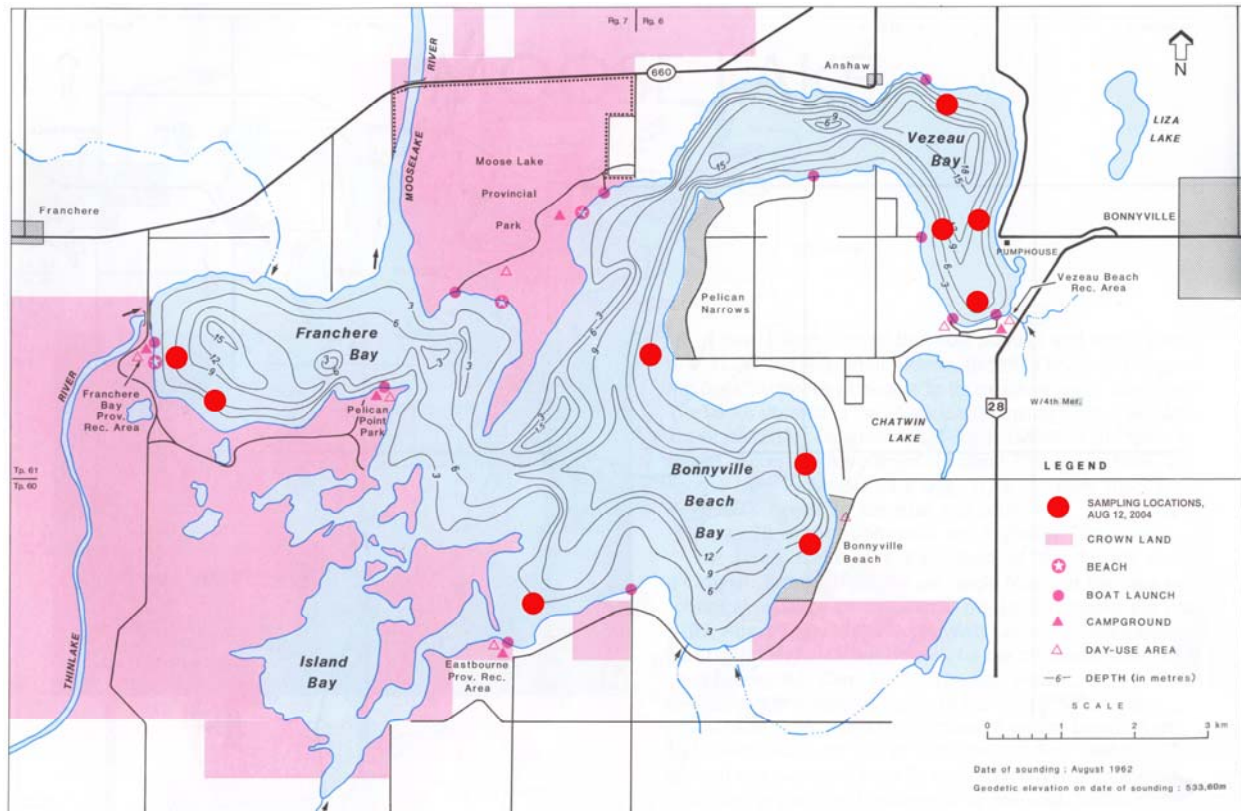


Figure 2: Water sample collections taken from Moose Lake August 12th, 2004. Red dots identify approximate sampling locations. Map adapted from Mitchell and Prepas (1990).

Caffeine Collections

Samples were collected by AQUALITY on Aug 12th, 2004, with the assistance of a volunteer from the Moose Lake *Water for Life* Committee. Ultra-clean 1L amber glass bottles were provided by the Alberta Research Council (Vegreville) for sample collection, and their pharmaceutical sampling protocol was followed. Samples were collected by field staff wearing inert vinyl gloves, by opening a sealed bottle underwater and letting it fill. Bottles were immediately capped and stored in coolers with ice packs. Care was taken to avoid sediment, algae and other debris from entering the collection bottles. Bottles were shipped overnight for delivery to the ARC labs in Vegreville. Both field staff and ARC laboratory staff were not allowed to consume caffeine on the respective days of collection or analysis, and great care was taken to ensure that no contaminants came into contact with samples or sample bottles.

Laboratory Analysis (ARC Vegreville)

Samples were kept cool (~4°C) until extraction, then transferred to a 2L separator funnel and spiked with appropriate surrogate standards. Liquid/liquid neutral extraction with dichloromethane was performed in triplicate, and the combined extracts were concentrated in a Turbo Vap tube. A hexane solvent exchange reduced the sample to approximately 5 mL, and the samples were further concentrated down to a volume of 1 mL. Samples were then analyzed by

GC–MS (gas chromatograph–mass spectrography) in total ion chromatogram (TIC) mode. For these samples, a four point calibration curve was prepared to provide a test sensitivity of 0.02 µg/L.

Sewage Caffeine Content Prediction

Before the first samples were collected, we predicted (based on human physiology statistics) that raw sewage should contain 42 µg/L of caffeine. This assumption was based on the following North American averages (adapted from Buerge et al. 2003):

Adult average urine volume produced per day = 1.4 L
Adult average urine caffeine concentration = 1500 µg/L
Adult urine caffeine produced per day = 2100 µg
Adult average urination frequency = 5 times daily
Volume of water per flush = 9.8 L/flush = 49 L/day

Adult caffeine produced per day = 2100 µg caffeine = 42 µg/L (Predicted)
Total amount of water 50.4 L

Using these assumptions and our known minimum detection limit for caffeine we calculate that it is possible to detect caffeine in lakes that has been diluted up to 2100 times.

Results:

All ten samples collected on August 12th 2004, all were below our 0.02 µg/L detection limit for caffeine.

Discussion:

Summary of Caffeine Results

Caffeine was not detected at any of the sites that were sampled, which suggests one of four things: (i) there is currently no raw human sewage entering the tested inflows, (ii) caffeine had naturally degraded below detection limits, (iii) detection limits were not sensitive enough to detect diluted caffeine levels; or (iv) caffeine was not present in the sewage (i.e. sewage had been partially treated). Even though current detection levels are in the order of 20 parts per billion, possible sewage concentrations at these locations may be diluted beyond the detection levels of our current analytical method.

Sources of Human Sewage in the Environment

Septic system leakage around Moose Lake is a cause for concern, as a comparison between septic tank waste and municipal wastewater indicated that septage may be 6 to 80 times as concentrated as typical domestic wastewater (Metcalf and Eddy, 1991). More specifically, total phosphorus was found to be 31 times more concentrated in septic tank wastewater than from municipal wastewater. The impact of phosphorus and nitrogen loading from septic tanks on the lake may be grossly underestimated from the phosphorus budgets calculated to date. Past

phosphorus budgets had estimated that sewage and runoff from urban and cottage areas contribute minor amounts (i.e. less than 2%) of phosphorus to the lake, based on studies at other Alberta lakes (Mitchell and Prepas, 1990). A phosphorus budget that specifically identifies the forms of phosphorus that are biologically available (i.e. soluble reactive phosphorus) should be calculated for the lake.

Urban sources of human waste include discharges from waste treatment lagoons, and outfall from combined sewers. Both of these types of discharge usually occur during or soon after periods of high precipitation, when water treatment systems cannot handle the extra volume of stormwater. Finally, human waste is sometimes applied on agricultural lands as a fertilizer, as it is very high in nutrients. If the fertilizer is improperly applied, or heavy precipitation occurs soon after application, it can subsequently be washed into the lake and other water bodies that drain into the lake.

Fate of Caffeine in the Natural Environment

In natural systems, caffeine is removed through lake flushing and through physical, chemical and biological degradation. Of all these processes, photodegradation by direct and indirect sunlight removes caffeine most effectively (Buerge et al. 2003). When wastewater is released into a sunny environment, caffeine has a half-life of approximately 12 days (Buerge et al. 2003). For our purposes this half life means that within 24 days, wastewater with detectable levels of caffeine can drop below our detection limit.

Conclusions

The lack of caffeine detects in Moose Lake is encouraging as it suggests that sewage dumping and faulty septic systems may have minimal contributions into the lake. However, as existing systems age and as populations increase, it becomes more likely that untreated human waste will enter Moose Lake. As stated previously, non-detects do not necessarily represent absence of caffeine and therefore human sewage, but rather that caffeine was not found at detectable levels. The extensive recreational and residential development the around the lake make it likely that human waste has entered Moose Lake in some way.

Recommendations

It is recommended that the caffeine sampling program continues on a small scale basis for monitoring and deterrence purposes. Sample collection timing could be altered in the future to more thoroughly address potential disposals throughout the year. At other Alberta lakes, caffeine detections have followed heavy rainfall events or during spring melt (Aquality 2004a, Aquality 2004b). Conversely, caffeine samples collected during dry periods have often resulted in non-detects. Possibly, the lack of flow during dry conditions slows seepage from septic tanks into adjacent water bodies. For this reason, we suggest moving the sampling schedule to earlier in the year to coincide with spring melt. Finally, an expanded sampling program could be undertaken to determine caffeine levels in the various streams and lakes of the Moose Lake watershed. Remote streams are often ideal candidates for unauthorized sewage disposal, and the simple fact that sampling is being performed on these streams would be a powerful tool to deter this practice.

Environmentally, sewage contains forms of nutrients that contribute to poor water quality and lead to excessive plant growths, algal blooms, fish kills and taste and odour problems. As these are all highly undesirable outcomes, there should be significant public support to detect and

remediate these problems. Sources of human waste in tributaries and lake waters can include dumping into the lake, streams or storm drains by septic pumpers or improper disposal by recreational vehicles. Septic tank inspections and cottager education could help address some of these issues. These activities are illegal and require enforcement by Alberta Environment, Alberta Municipal Affairs, and the Aspen Regional Health Authority.

In terms of human health, sewage in Moose Lake would be a cause for concern. Human waste is known to contain several pathogens, viruses, bacteria and other substances which can have an adverse effect on human health. If caffeine is detected in the future, contact recreation should be limited at those sites where caffeine has been detected, until follow-up sampling by the Aspen Regional Health Authority for coliforms shows that these sites are safe for recreational use.

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