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WATER TREATMENT OPTIONS FOR REMOVAL OF GIARDIA LAMBLIA IN CARCROSS, YUKON TERRITORY

K. R. Johnson
Project Engineer, Arctic Engineering Division,
UMA Engineering Ltd., 17007 - 107 Avenue,
Edmonton, Alberta, T5S 1G3

ABSTRACT

Carcross, Yukon Territory is a community of approximately 250 people, located 74 kilometres south of Whitehorse. In 1989 the Yukon Territorial Government proposed the use of a nearby lake as a new drinking water source. This new source would replace the existing groundwater source, which was producing water with elevated levels of nitrate, nitrite, and arsenic.

UMA Engineering Ltd. completed the preliminary engineering study for a new surface water intake system in 1989. The new surface water intake system was constructed in the winter of 1990. Subsequent to this study, an investigation undertaken by the University of Calgary in 1990 concluded that surface water supply systems in the Yukon are vulnerable to contamination from Giardia lamblia cysts.

Based upon the concern over this potential contamination UMA completed a report on water treatment options for G. lamblia removal. This report investigated the options of slow sand filtration, rapid sand filtration, multi-media filtration, precoat filtration, and cartridge filtration. The report compared performance, capital costs, and operation and maintenance costs for the 5 options.

The report concluded that a slow sand filter system, or a cartridge filter system would be the most simple and inexpensive options for the community with respect to cost. However, based upon the performance data available on the two options for removal of G. lamblia cysts, the report recommended the implementation of a slow sand filtration system. The report also recommended disinfection and sufficient contact time be utilized in conjunction with a slow sand filter to maximize the reduction of G. lamblia cysts.

RÉSUMÉ

Choix de traitement pour l'enlèvement de Giardia lamblia dans l'eau potable de la municipalité de Carcross, Territoire du Yukon.

K. R. Johnson, Ingénieur de projet, division du Génie Arctique, UMA Engineering Ltd., 17007 - 107 Avenue, Edmonton, Alberta, T5S 1G3

La communauté de Carcross compte environ 250 personnes et est localisée à quelques 75 kilomètres au sud de Whitehorse, au Yukon. En 1989, le Gouvernement du Territoire du Yukon proposa d'utiliser comme nouvelle source d'approvisionnement en eau potable un lac situé à proximité. Cette nouvelle source devait remplacer les eaux souterraines utilisées jusqu'à présent; ces dernières contenaient des niveaux élevés de nitrates, de nitrites et d'arsenic.

UMA Engineering Ltd. compléta, en 1989, l'étude préliminaire de l'ingéniérie du nouveau système d'ápprovisionnement en eau. Le système fut construit en 1990. Peu après, une étude menée par l'Université de Calgary (en 1990) conclut que les systèmes s'approvisionnant en eaux de surface au Yukon étaient vulnérables à la contamination par les kystes de G. lamblia.

En réaction à cette possibilité de contamination, UMA prépara un rapport portant sur les différentes options de traitement permettant l'enlèvement de G. lamblia. On y examine plusieurs alternatives de traitement: filtration lente sur sable, filtration rapide sur sable, filtration multicouche, filtration avec précouche, et filtration en cartouche. Pour les cinq options, la performance et les coûts de capitalisation, d'opération et de maintenance sont comparés.

Le rapport conclut que la filtration lente sur sable et la filtration en cartouche sont les deux choix les plus simples et les moins coûteux pour la communauté. Cependant, à cause de son efficacité d'enlèvement des kystes de G. lamblia, on recommande l'implantation d'un système de filtration lente sur sable. Le rapport indique également que cette filtration devrait être suivie d'une désinfection avec un temps de contact suffisant, si on veut maximiser la réduction des kystes de G. lamblia.

INTRODUCTION

Background

Carcross is an unincorporated community with a population of approximately 254 people (1989), located 74 kilometres south of Whitehorse, Yukon. The community is situated on both the north and south shores of the narrows which join two lakes.

The primary source of drinking water to households was a community well, which worked in conjunction with a trucked delivery system. Unfortunately, the well water source has been subject to increasing contamination from high concentrations of nitrate and nitrite. This was apparently caused by the subsurface sewage disposal systems in the community. In addition, high arsenic levels were found in the community well and a number individual wells. An activated alumina treatment system was installed in 1986 to reduce the arsenic levels in the community well water, and households were instructed to discontinue use of individual wells.

In 1989, in response to this increased water supply contamination, the Yukon Territorial Government proposed the use of one of the lakes as a new drinking water source. A preliminary report by UMA Engineering Ltd. (Carcross Water and Wastewater Predesign Report, 1989) recommended the construction of a submerged intake system in one of the lakes. The new surface water supply system was constructed during the winter of 1990.

In November 1990, the Yukon Territorial Government requested that UMA Engineering Ltd. undertake a study on alternative treatment options for removal of Giardia lamblia from the new surface water supply system. This study was in response to a report prepared by the University of Calgary (Roach et al, 1990) which stated that Yukon communities which utilize surface water supplies "are vulnerable to contamination of their water supplies with G. lamblia cysts."

Giardia lamblia

Giardia lamblia has been recognized as the cause of the most commonly identified water intestinal disease in North America, referred to as giardiasis (Lin, 1985). Giardiasis is not fatal, but can be extremely uncomfortable; the symptoms include diarrhea, weakness, fatigue, dehydration, and weight loss. Giardia lamblia may exist in either a parasite form and cyst form, depending upon the conditions; in an unfavourable environment the parasite will form a cyst.

The transmission of giardiasis may occur by ingestion of the cysts in contaminated drinking water and foods. It is believed that wild and domestic animals such as beaver, rats, rabbits and dogs may play an important role in the transmissions of giardiasis to humans (Lin, 1985).

The treatment technology for cyst destruction or removal includes disinfection and filtration. Disinfection practices for cyst destruction require special attention because standard methods may not be adequate in destroying cysts. Water treatment by slow sand filtration, rapid sand filtration (with proper coagulation), and precoat filtration may be used to remove cysts. However, disinfection and filtration should both form part of a treatment process for cyst reduction to provide a dual barrier for treatment.

Objectives of Study

The objectives of the study water treatment options for the removal of Giardia lamblia in the community of Carcross were:

- Identify treatment options which may provide protection to the community water supply from contamination by Giardia lamblia and other pathogenic organisms.
- Identify advantages and disadvantages for each treatment option in its application in the community.
- Identify relative capital, operation and maintenance costs for each treatment option.

DESIGN REQUIREMENTS FOR THE TRUCKED WATER SUPPLY SYSTEM

Design Flow

An average day trucked water design consumption of 120 L/c/d was identified in the Carcross Water and Wastewater Predesign Report (UMA, 1989). Based upon a design population of 362 projected for the year 2001 (3 percent annual growth for a 10 year horizon), the design flow would be 43,500 litres per day, or 0.50 L/s (1.81 m^3/hour) based upon continuous operation of the facility.

The current trucked water delivery system operates eight hours per day, three days per week, therefore without any balancing water storage the design flow of the treatment system would have to conform to this schedule. Given the scenario where the design flow for a given week would be delivered during three 8 hour periods during the week, the treatment facility should have a capacity of 3.52 L/s.

Balancing Water Storage

Balancing capacity in the form of treated water storage will reduce the design flow required for the filtration system by a factor of 7 (3.52 L/s to 0.50 L/s). If 120 cubic metres of treated water storage is available, the filtration system may supply the trucked water demand operating continuously at 0.50 L/s (43.5 m^3/day). Balancing water storage is also a desirable requirement for the trucked water delivery system to provide contact time for disinfection, meet the flow requirements to efficiently operate a trucked water delivery system and optimize the operation of a filtration facility.

FILTRATION ALTERNATIVES FOR GIARDIA LAMBLIA REMOVAL

Slow Sand Filtration

Slow sand filters are a biologically active sand system, which accommodate enhanced removal of particulate material with the low hydraulic loading rate, and the development of a biological slime. It is ideal for small communities, where the filter structure itself may form part of earthen basins or concrete basins.

A slow sand filter requires relatively little attention for operation and maintenance. Periodic cleaning is necessary when the head loss raises the water level beyond the headloss allowance of the filter chamber. The cleaning is completed by removing several centimetres of sand from the top of the filter.

Finch et al (1985) commented that studies on the performance of slow sand filters in removing G. lamblia cysts reported removal in excess of 98% (1.7 log reduction) under a variety of operating conditions. Bellamy et al (1985) reported removal exceeding 98% for a variety of conditions as well as an average 4.2 log reduction (>99.99% removal) for an established biological system in the sand.

The simple operation of a slow sand filter along with the potentially high reduction of G. lamblia are the major advantages for application of this option in Carcross. The major disadvantage is the relatively large surface area required for the filter constructed with an earthen basin, however area restrictions in Carcross necessitate the use of concrete basins.

Rapid Sand Filtration

Rapid sand filtration systems generally utilize slightly coarser granular media than slow sand filters, and operate at hydraulic loading rates much greater than slow sand filters. The higher hydraulic loading rate of a rapid sand filter necessitates backwashing of filters on a regular basis, and consequently the filter structure includes a wash water trough and a wash water tank.

The recommended operation of a rapid sand filter usually includes pretreatment in the form of coagulation, flocculation and sedimentation. This greatly improves the operating efficiency of the filter by removing larger suspended material prior to filtration.

Finch et al (1985) commented that studies on the performance of rapid sand filters in removing G. lamblia cysts reported removal of 99.98 percent (3.7 log reduction). These removals were based on the use coagulation and sedimentation as a means of pretreatment. A study by Al-Ani and Hendricks (1983) reported an average reduction of 99.56% in G. lamblia (2.4 log reduction) for a rapid sand filter.

The most effective application of filtration technology in the community of Carcross would be the installation of a package water treatment plant. This package treatment unit has advantages with respect to construction costs, particularly for such a small unit. The major disadvantage of rapid sand filtration is the relative complexity to operate such a system.

Multi-Media Filtration

Multi-media filters are similar to rapid sand filters except that they utilize two or more types of filter material or varying sizes and densities. Multi-media filters may consist of anthracite coal and sand, or anthracite coal, sand and garnet. The configuration of multi-media filtration system is very similar to the rapid sand filtration system.

The use of material with different sizes and densities accommodates grading of the filter material from coarse material on the surface to fine material at the base. This arrangement permits higher loading rates and longer filter runs than with a rapid sand filter, which in turn may lead to more economical filter operation. The operation and maintenance for a multi-media filter is essentially identical to the rapid sand filter.

Finch et al (1985) reported that studies of multi-media filtration produced consistently better results than for rapid sand filtration based upon removal of particles (greater than 99 percent removal of particles). The study by Al-Ani and Hendricks (1983) reported an average reduction of 99.15% in G. lamblia (2.1 log reduction) for a multi media filter. Bryck (1983) noted an average reduction of 97% (1.5 log reduction) of particles in the 5 to 15 micron range for a pilot scale operation of a multi-media filtration system.

Precoat Filtration

Precoat filters are a single media filter which utilize a thin layer of extremely fine granular material (diatomaceous earth or man-made material) positioned on a permeable support. The very fine filter media (0.05 mm to 0.001 m) is responsible for a high quality effluent, however the media is sensitive to turbid water. This sensitivity is overcome to some extent with the continuous feed of filter media ("body feed") to the system.

The operating cycle for a precoat normally involves deposit of the precoat material on the permeable support to form a filter cake. The filter operates continuously until either the head losses across the filter become too great or the filter cake begins to slough. The contaminated precoat is then completely washed from the support system and the operating cycle begins again.

The operation of a precoat filtration system is possibility the most technically demanding of the granular media filtration systems. Lawrence (1991) stated that diatomaceous earth filters must be operated "near perfect" during every start-up cycle in order to guarantee a properly functioning precoat layer.

Finch et al (1985) reported that studies on the removal of G. lamblia by precoat filtration produced 99.8 percent (2.7 log reduction) or greater removal of cysts, or cyst sized particles. Earlier studies reported 99.99 percent (4 log) removals by precoat filtration on particles similar to G. lamblia cysts. Bryck (1983) noted a 99% reduction (2 log reduction) of particles in the 5 to 15 micron range for a pilot scale operation of a diatomaceous earth filter.

The operating requirement is the major disadvantage to a precoat filtration system for the community of Carcross even though the system may achieve very good levels of G. lamblia cyst removal.

Cartridge Filtration

Cartridge filters are a fibre media filter which utilize a bonded fibre mat mounted plastic cartridge (0.6 m^2 per cartridge), and configured in units of cartridge clusters. The bonded fibre mat may consist of resin bonded cellulose, glass or acrylic fibres.

A cartridge filter system may remove particles to a nominal 0.35 micron size depending upon the specified cartridge. The filter cartridge clusters are generally housed in stainless steel structures which are designed for easy replacement of the cartridges.

Pretreatment of the "raw" water for the cartridge filters by granular media filtration may be necessary to permit reasonable operating life of the filter cartridges. A granular media filter system may minimize filter "blinding" from the suspended material in the raw water. Regular replacement of cartridge filters is necessary, but this is dependent upon the water quality of the effluent leaving the granular media filter.

Although cartridge filters utilize a completely different media from granular filters, they may provide a comparable reduction of G. lamblia. A study by Applied Consumer Services Inc. (1991) reported a 99.2% removal of G. lamblia cysts (2.1 log reduction) utilizing a 0.35 micron nominally rated filter. However, the data on cartridge filters is very limited, therefore, the performance of this type of system is questionable.

COST ESTIMATES

The capital cost estimates prepared for the various water filtration options are based upon preliminary information compiled in-house and from various supplier sources (see Table 1). For the purpose of comparison the cost estimates were prepared on similar scenarios for all of the options. The treatment scenarios were sized on a 1 L/s treatment capacity because of the minimum capacity available for the package treatment units. The treatment scenarios also include 120 m^3 of above ground balancing storage ($85,000), a heated building to house the treatment units, and a 30 percent engineering and contingency allowance.

TABLE 1
CAPITAL COSTS FOR FILTRATION OPTIONS
(1991 DOLLARS)

Option	Capital Cost
Slow Sand Filtration	$354,000
Rapid Sand or Multi-Media Filtration	$527,000
Precoat Filtration	$463,000
Cartridge Filtration	$317,000

The operation and maintenance costs include a part time plant operator (hourly basis), an energy allowance, media replacement, and treatment chemicals (where required). (See Table 2.) The operator attention for the various treatment systems included 1/2 hour per day for slow sand filtration; 2 hours per day for rapid sand and multi-media filtration; 3 hours per day for precoat filtration; and 1 hour per day for cartridge filtration.

TABLE 2
ANNUAL OPERATION AND MAINTENANCE COSTS FOR FILTRATION OPTIONS (1991 DOLLARS)

Option	Operation and Maintenance Cost
Slow Sand Filtration	$13,500
Rapid Sand or Multi-Media Filtration	$31,900
Precoat Filtration	$47,600
Cartridge Filtration	$20,500

DISCUSSION

The potential reduction of G. lamblia cysts for the various filtration options may exceed a 2 log reduction for all of the options, based on the information in the literature. Slow sand filtration and precoat filtration appear to have the highest potential for Giardia reduction, which may exceed a 4 log reduction. The literature on the performance of cartridge filters for G. lamblia cyst removal is very limited, therefore this system may not perform as well as the granular media systems.

A comparison of the capital costs of the various systems versus the reduction of Giardia lamblia suggests that multi-media filtration, rapid sand filtration and precoat filtration are not the most cost effective means of filtration. Slow sand filtration and cartridge filtration appear to be the most cost effective means of reducing Giardia lamblia. Slow sand filtration becomes even more cost effective when the operating costs are also considered.

CONCLUSIONS

All of the filtration systems discussed in this report, in conjunction with adequate disinfection and contact time will minimize the potential for drinking water contamination from Giardia lamblia, as well as other pathogenic organisms.

Based upon the capital costs identified for each system, a slow sand filter or the cartridge filter appear to be the most inexpensive options to serve the trucked water delivery demands of the community of Carcross for a 10 year horizon. However, based on the current literature available, the cartridge filter system may not perform as well as a slow sand filter.

A slow sand filter offers the simplest operating system, as well as lowest potential for operating difficulties. Based upon the operating costs for each system, a slow sand filter appears to be the most inexpensive option to operate and maintain. Treated water balancing storage, as previously described, is an integral part of the system to provide contact time for disinfection, meet the flow requirements to efficiently operate the trucked water delivery system, and optimize the operation of a filtration facility.

RECOMMENDATIONS

A slow sand filtration system with a capacity of 1.0 L/s along with 120 m^3 of treated water storage is recommended to supply the trucked water delivery demands for the Community of Carcross for a ten year horizon. The recommendation is based upon consideration of capital cost, operating cost, ease of operation, and potential reduction of Giardia lamblia.

The slow sand filter system in conjunction with disinfection and sufficient contact time will minimize the potential for drinking water contamination from Giardia lamblia and other pathogenic organisms.

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ETUDE SUR MODELE REDUIT DE L'AMONT DES DESSABLEURS DE LA STATION DE TRAITEMENT DES EAUX USEES DE L'EST DE LA CUQ

CHOUIKH, Abderrahmane — ROUSSEAU, Paul

Consortium PCRB, 410 Boul. Charest est, bureau 400
Québec (Quebec), G1K 8G3

RÉSUMÉ

L'étude sur modèle réduit avait comme objectif, à partir d'un aménagement physique préliminaire du secteur amont des dessableurs de la station Est, de:

1) vérifier que les dimensions et le comportement hydraulique prévus sont réalistes;

2) faire les ajustements à la conception, si nécessaire, afin d'avoir un fonctionnement adéquat; et

3) explorer différentes configurations d'opération telles que fermeture de grilles ou de dessableurs en diverses situations de débit.

L'étude sur modèle réduit a permis, tout en répondant aux différents aspects reliés aux objectifs tels que répartition des débits..., de mettre en lumière plusieurs problèmes potentiels, notamment sur le plan des relations charge-débit et de singularités locales de l'écoulement ayant des conséquences sur le comportement sédimentologique.