ACHIEVING BENEFITS THROUGH GREYWATER TREATMENT AND REUSE IN NORTHERN BUILDINGS AND COMMUNITIES

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Terragon Environmental Technologies Inc. is an award-winning cleantech company founded in 2004 and based in Montréal, Québec. Terragon develops simple appliances for solid waste, wastewater, and sludges that enable any habitat to treat its own waste locally with no environmental damage and with significant benefits from the recovery of valuable resources.

Abstract

Greywater (GW) treatment and reuse is usually associated with regions facing water shortages. While some Arctic regions do lack sources of water, GW treatment and reuse may be of interest to most regions, since they typically have a high cost of truck-delivered potable water, low per capita consumption, and challenges with wastewater management. A suitably designed GW treatment system that takes into account northern constraints could provide significant benefits. Treated GW could be used for toilet flushing and other non-potable applications, thus reserving costly potable water for uses requiring this quality while also minimizing the volume of wastewater generated. In preparation for a GW treatment demonstration project in Cambridge Bay, Nunavut, a novel GW treatment system was evaluated over a six-month period. The system treated real shower and laundry GW, in some cases adjusted to more closely resemble GW expected to be found in the North. Treatment performance was compared with the NSF/ANSI 350 standard for residential and commercial buildings. It was found that the GW treatment system operated reliably and was able to meet the requirements of the NSF/ANSI 350 standard for all GW tested.

Résumé

Le traitement et la réutilisation des eaux grises (EG) sont habituellement associés à des régions aux prises avec des pénuries d'eau. Bien que certaines régions arctiques n'aient pas de sources d'eau, le traitement et la réutilisation des EG peuvent intéresser la plupart des régions, puisqu'elles doivent généralement gérer un coût élevé d'approvisionnement en eau potable par camion, une faible consommation par habitant et des problèmes de gestion des eaux usées. Un système de traitement des EG bien conçu qui tient compte des contraintes du Nord pourrait offrir des avantages importants. Les EG traitées pourraient être utilisées pour la chasse d'eau des toilettes et d'autres applications non potable, ce qui permettrait de réserver de l'eau potable coûteuse pour des utilisations nécessitant cette qualité tout en réduisant le volume d'eaux usées produites. En prévision d'un projet de démonstration de traitement des EG à Cambridge Bay, au Nunavut, un nouveau système de traitement des EG a été évalué sur une période de six mois. Le système traitait de véritables EG de douche et de lessive, dans certains cas ajustées pour ressembler davantage aux EG qui devraient se trouver dans le

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Nord. Le rendement du traitement a été comparé à la norme NSF/ANSI 350 pour les immeubles résidentiels et commerciaux. On a constaté que le système de traitement des EG fonctionnait de façon fiable et pouvait satisfaire aux exigences de la norme NSF/ANSI 350 pour toutes les EG testées.

Introduction

Cambridge Bay is a hamlet located on Victoria Island in the Kitikmeot Region of Nunavut, Canada. In 2016, the population was 1,716, with the majority of residents being Aboriginal (Inuit) (Statistics Canada 2016). Because of permafrost and the harsh climate in Cambridge Bay, piped-water-distribution systems (underground or overground) and wastewater-collection systems are extremely costly and impractical. Thus, as in most Nunavut communities, homes and businesses in Cambridge Bay are equipped with separate water- and sewage-holding tanks for truck delivery of potable water and truck collection of wastewater. These truck services are provided for a fee by the hamlet, with different rates for residential and commercial customers. Potable water is generated from treated surface water and wastewater is disposed of in a nearby sewage lagoon.

The Cambridge Bay cost of water (economic rate) is \$75/m^3 (including delivery and pump-out), although with government subsidies, the cost is reduced to \$23/m^3 for commercial customers and \$6/m^3 for non-commercial customers (Hamlet of Cambridge Bay By-Law 232). For comparison, combined water and wastewater rates and fees in major Canadian cities are generally less than \$5/m^3 for residential and commercial customers. Residential per capita water use in Nunavut is typically around 100 L/day, which is approximately one third of the Canadian average (Daley et al. 2014). Additionally, Nunavut's diesel-generated electricity cost is approximately 5 to 10 times higher than in other Canadian regions.

Treating greywater (GW) from bathing and laundry activities and storing it in a separate treated GW tank for use in applications that do not require potable water (e.g., toilet flushing and laundry) is an approach which could be considered to reduce costs and reserve clean water for those applications that truly require potable quality (i.e., drinking, cooking, and bathing). GW reuse can also decrease the per capita volume of potable water required and volume of sewage generated. GW reuse could ease the load on potable water treatment facilities and/or truck delivery services that may be operating near capacity in some communities. Commercial water users may be especially interested in GW reuse, given that they pay considerably more for their trucked services than residential customers.

GW treatment and reuse generates high interest in many regions of North America because of water shortages resulting from drought and/or a mismatch between water availability and domestic, agricultural, and industrial needs. However, GW treatment and reuse has rarely been considered for the North because of various challenges, including technical, practical, and social challenges. In this project, a novel GW treatment system will be evaluated and demonstrated to assess its suitability for treating GW generated in northern settings. Following this, the best options for deriving benefits from GW treatment and reuse in the North will be identified using techno-economic analyses and feedback from local community residents, gathered by Nunavut Arctic College students.

This paper contains the results of a six-month evaluation of the GW treatment system carried out in Montréal in preparation for the system installation in a triplex residence (Fig. 1) at the Canadian High Arctic Research Station (CHARS).

Figure 1: Triplex residence at the Canadian High Arctic Research Station (CHARS), where the greywater system will be installed in November 2018.

Challenges for greywater treatment in the North

Many GW treatment and reuse initiatives occur in warm climates where treatment equipment can be located outside. For the North, consideration has to be given to installing GW treatment systems inside buildings or heated enclosures. Many northern homes are small, sometimes overcrowded, and built on stilts (piles) because of permafrost; thus, residential single-family homes generally have no basements and no space available to accommodate GW treatment equipment. GW systems may be more easily and preferentially integrated into other types of buildings (i.e., multi-occupancy, commercial, governmental, educational) or at a central receiving site where GW from several separate sources is accepted and treated. Finally, some commercially available GW treatment approaches rely on treatment trains that are not compatible with northern operation, because of consumable requirements (e.g., chemicals) and maintenance requirements or the inability to treat northern GW to accepted GW-reuse standards.

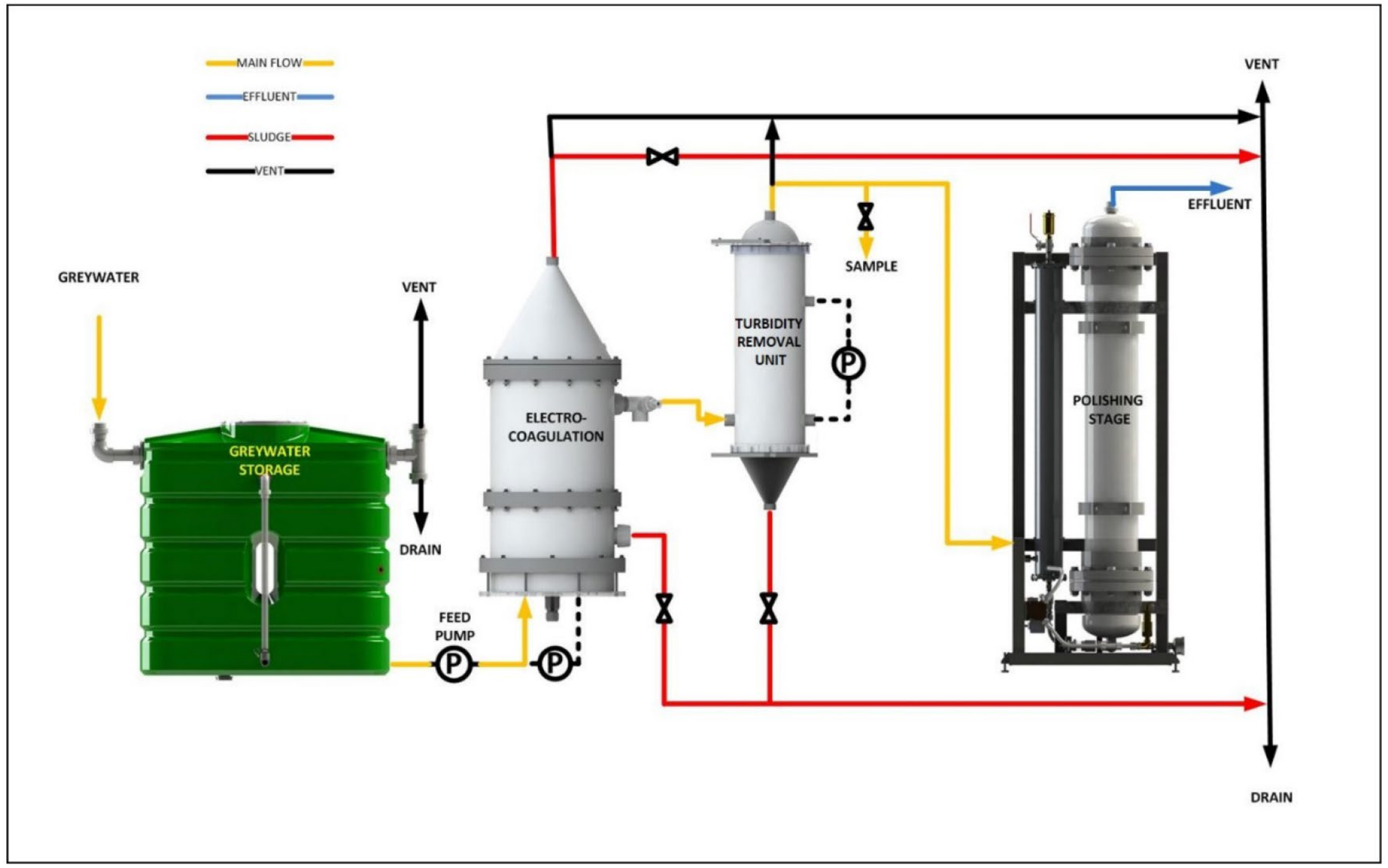

Figure 2: Schematic of the greywater treatment system.

Greywater treatment system set-up for evaluation

A novel automated GW treatment system not based on chemical addition or biological treatment was assessed over a six-month period. The system was operated Monday to Friday during the day only. The system had a capacity of 1.44 m^3/day, required about 0.5kW to operate, and is shown schematically in Figure 2. It consisted of a GW receiving tank to collect GW (from showers and laundry), a patent-pending electrocoagulation unit serving to remove the majority of particulate contaminants and organic loading, a turbidity removal unit, and lastly, an adsorption column for final polishing. The treated GW was collected in a storage tank and disinfection was achieved using an in situ electrochemical process. During the evaluation, the electrocoagulation electrodes were replaced once, using a 10-minute procedure.

The GW treatment system was installed in the basement of a Montréal college sports complex (Fig. 3); the system to be installed at CHARS will be more compact and enclosed. GW that was treated came from the showers as well as from a domestic washing machine used to wash team uniforms and employee laundry. The treated GW was used as flush water for a nearby toilet — this aspect is important because a previous investigation indicated that over time, improperly treated GW can have negative impacts on toilet flush mechanisms and result in biofilm growth in the tank (Kuru and Luettgen 2012).

Figure 3: Greywater treatment system set-up used during the evaluation in Montréal.

Greywater reuse standards

For decentralized greywater treatment, NSF International developed a 2011 standard (NSF/ANSI 350: *Onsite Residential and Commercial Water Reuse Treatment*), which describes the required criteria for water reuse systems. The standard has now been adopted by plumbing and building codes, and was used in this project to assess the performance of the novel GW treatment system. The treatment thresholds for residential (≤5,678 L/day) and commercial (> 5,678 L/day) applications are presented in Table 1.

Greywater characterization and composition

The mixed GW from showers and laundry, as well as GW from showers alone and laundry alone, were sampled over a two-week period and fully characterized. The results are presented in Table 2, where it can be seen that the strength of the GW from laundry alone is an order of magnitude higher than that of GW from showers alone. Following this initial GW characterization period, selected GW parameters were measured each week throughout the six-month trial; typically these included, at a minimum, the chemical oxygen demand (COD), biochemical oxygen demand (BOD5), and total suspended solids (TSS).

Table 1: NSF/ANSI 350 greywater treatment requirements for residential (Class R) and commercial (Class C) reuse.

		Class R		Class C	
Parameter	**Units**	**Overall test average**	**Single sample maximum**	**Overall test average**	**Single sample maximum**
CBOD5	(mg/L)	10	25	10	25
TSS	(mg/L)	10	30	10	30
Turbidity	(NTU)	5	10	2	5
E.coli[2]	(MPN/100 mL)	14	240	2.2	200
pH	(SU)	6 - 9	NA[1]	6 - 9	NA
Storage vessel disinfection	(mg/L)[3]	≥0.5 - ≤2.5	NA	≥0.5 - ≤2.5	NA
Color		MR[4]	NA	MR	NA
Odor		Non-offensive	NA	Non-offensive	NA
Oily film and foam		Non-detectable	Non-detectable	Non-detectable	Non-detectable
Energy consumption		MR	NA	MR	NA

[1] NA = Not applicable

[2] Calculated as geometric mean

[3] As chlorine. Other disinfectants can be used.

[4] MR = Measured and reported only

Table 2: Characterization of greywater from shower water (SW) and laundry water (LW).

		3-Sep-17	21-Sep-17	26-Sep-17	28-Sep-17	10-Oct-17
Parameter	**Units**	**Sample 1 (SW)**	**Sample 2 (SW+LW)**	**Sample 3 (SW+LW)**	**Sample 4 (SW+LW)**	**Sample 5 (LW)**
COD	(mg/L)	122	208	133	218	1840
BOD_5	(mg/L)	70	120	87,5	117,5	655
TSS	(mg/L)	19	36	23	15	340
PT	(mg/L PO_4^{3}-)	4,5	2,6	3,64	5,25	-
pH	-	7,69	7,94	7,84	8,46	7.51
Conductivity	(µs/cm)	512	496	465	554	621
Turbidity	NTU	13,2	38,7	20,9	15,3	483
Alkalinity	(mg/L $CaCO_3$)	162	150	132	185	-
$N\text{-}NH_3$	(mg/L)	16,4	11,3	10,25	18	-
TOC	(mg/L)	26,3	44,1	21,9	53,8	-
TKN	(mg/L)	-	15,1	-	26,7	42.4
Oil & Grease	(mg/L)	-	20	-	15	252
Fecal Coliform	(UFC/100 mL)	-	72	-	-	170 000
Total Coliform	(CFU/100 mL)	-	800 000	-	-	800 000
E.coli	(CFU/100 mL)	-	60	-	-	5000

The GW generated during the six-month trial was derived from activities making use of the potable water available in Montréal. However, potable water available in Cambridge Bay (and many other northern regions) can have somewhat different characteristics, often containing a greater amount of natural organic material (NOM) derived from the breakdown of plant and animal material. The main component of NOM is humic acid; humic substances typically account for 40%–80% of the dissolved organic matter in water, with lesser contributions from fulvic acid (Uyguner 2007).

During a visit to Cambridge Bay in late July 2017, tap water at the CHARS triplex was found to have a COD of 8–22 mg/L, as determined by a Mantech PeCOD analyzer (0.7 mg/L detection limit); source water used to create the potable water was also found to have similar COD values, assumed to be due primarily to NOM. Northern water may also contain disinfection by-products, minerals, and heavy metals, depending on the surface water source and the potable water treatment process used.

To investigate the potential impact of NOM on GW treatment, GW produced by the Montréal college was spiked with known quantities of humic acid (Plant Products Ez-Gro 80% Humic Acid). As well, Montréal potable water not contaminated by any GW was spiked with high concentrations of humic acid and then treated with the GW treatment process.

Greywater treatment results

After several trial periods during which the electrocoagulation unit was operated at different current intensities, an optimal current intensity was selected and used for the remainder of the trial (November 2017 to mid-February 2018). Figures 4 and 5 present the GW influent and GW effluent values for COD, BOD5, TSS, and turbidity. The NSF/ANSI 350 treatment standards presented in Table 2 were met, and pH (not shown) remained within the range of 6–9, as required.

The influence of NOM on the GW treatment was investigated by adding humic acid to the GW present in the collection tank, with the goal of achieving an NOM concentration of approximately 30 mg/L. Once added to the GW collection tank, it was unfortunately not possible to effect any mixing of the NOM concentrate with the GW. The COD of the GW being sent to the treatment system after the NOM addition attained a maximal value of 1,235 mg/L, and over a period of one hour gradually

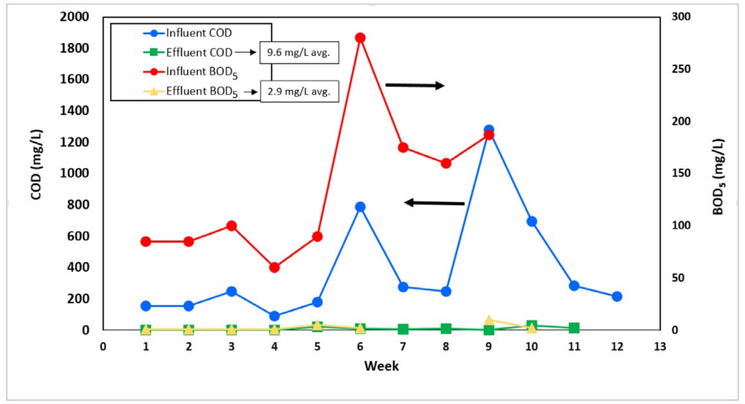

Figure 4: Greywater influent and greywater effluent COD and BOD5.

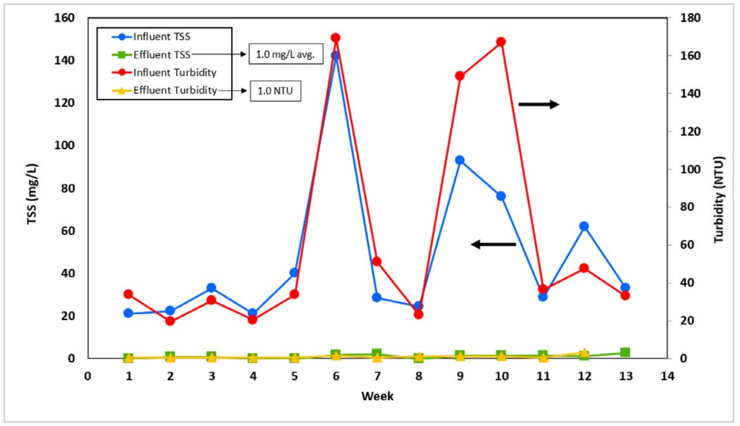

Figure 5: Greywater influent and greywater effluent TSS and turbidity.

decreased to 584 mg/L (still considerably higher than the typical GW influent COD value). Despite this high GW influent COD, the GW treatment was still successful in meeting the NSF/ANSI 350 standards. Another trial was next carried out to see if the GW treatment process could be used to treat a highly concentrated solution of humic acid (150 ppm of Plant Products Ez-Gro 80% Humic Acid) in potable water not contaminated by any GW. Figure 6 shows that the treatment process was still highly effective, and thus it can be concluded that northern GW can be treated to NSF/ANSI 350 standards even if such GW is generated from potable water containing a background concentration of NOM.

Regarding disinfection, microbiological parameters were measured periodically, and the values obtained are presented in Table 3. The electrochemical approach used to generate oxidants in situ in the GW effluent holding tank was successful in creating a small chlorine residual between 0.5 and 2.5 mg/L and in reducing the E. coli to 14 CFU/100 mL, as required by NSF/ANSI 350.

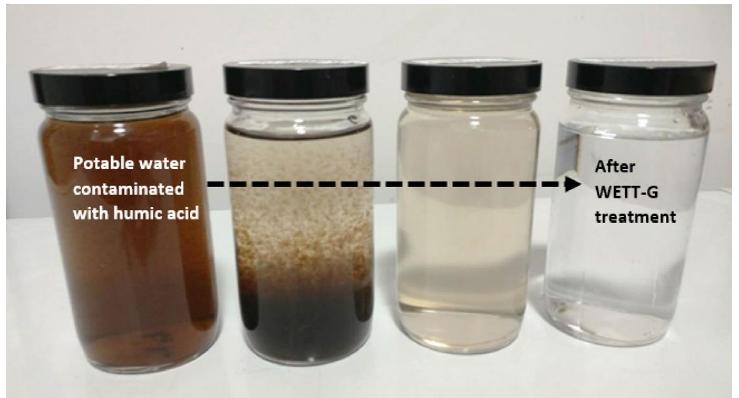

Figure 6: Montréal potable water spiked with humic acid and treated with the greywater treatment system.

No biofilm was observed in the toilet tank over the six-month period and no issues were encountered with the flushing mechanism.

Community considerations

Beyond techno-economic aspects, an important consideration for the success of a GW treatment initiative, not only in the North but anywhere, is the receptivity of the concept by community residents. The deeply rooted Inuit cultural and social perceptions regarding water will be investigated through a series of surveys and exchanges with local residents, carried out by Nunavut Arctic College students.

Conclusions

The novel greywater treatment technology was able to reliably treat real greywater generated from showering and laundry activities at a Montréal college over a period of six months. The treated GW characteristics respected the requirements set forth by the NSF/ANSI 350 standard for greywater treatment. Even when greywater or potable water was doped with high concentrations of NOM, in the form of humic acid such as may be found in northern GW, these same results were achieved.

Acknowledgements

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Table 3: Greywater disinfection results.

Sample	Microbiological Analysis	Units	Untreated Greywater	Untreated Greywater	After Disinfection	Free Chlorine (mg/L)	Initial pH	Final pH
15-11-2017	Fecal Coliform	(CFU/100 mL)	2900	<10	<10	-	7.81	7.4
	Total Coliform		CTN[1]	<10	<10			
	E. Coli		2400	200	81			
21-11a-2017	Fecal Coliform	(CFU/100 mL)	30 000	<10	<10	-	7.03	7.66
	Total Coliform		>800 000	36000	<10			
	E. Coli		500	<10	<10			
28-11-2017	Fecal Coliform	(CFU/100 mL)	210	<10	<10	1.34	7.37	7.6
	Total Coliform		>800 000	7900	<10			
	E. Coli		99	<10	<10			
5-12-2017	Fecal Coliform	(CFU/100 mL)	1400	<10	<10	1.2	7.69	7.99
	Total Coliform		>800 000	550	<10			
	E. Coli		2400	<10	<10			
12-12-2017	Fecal Coliform	(CFU/100 mL)	<10	<10	<10	0.11	6.69	7.55
	Total Coliform		>800 000	11000	310			
	E. Coli		98	<10	<10			
13-02-2018	Fecal Coliform	(CFU/100 mL)	-	-	-	0.18	7.96	7.83
	Total Coliform		>600 000	-	<10			
	E. Coli		990	-	<10			

[1] CTN = Colonies too numerous to measure

References

Daley K., Castleden, H., Jamieson, R., Furgal, C., and Ell, N. 2014. Municipal water quantities and health in Nunavut households: An exploratory case study in Coral Harbour, Nunavut, Canada. *International Journal of Circumpolar Health* 73:23843. doi:10.3402/ijch.v73.23843. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3970036/ [accessed 29 March 2018].

Hamlet of Cambridge Bay, NU. By-law No. 232–Schedule A: Water and sewer rates for municipal services. 24 pp. Available from http://www.cambridgebay.ca/sites/default/files/By-Law%20232%20-%20Water%20Sewer.pdf [accessed 29 March 2018].

Kuru, B. and Luettgen, M. 2012. Is gray-water reuse ready for prime time? Available from https://www.us.kohler.com/webassets/kpna/pressreleases/2012/KOHLER-GRAYWATER_111412.pdf [accessed 30 March 2018].

Statistics Canada. Census profile, 2016 census, Cambridge Bay [population centre], Nunavut and Nunavut [Territory]. Available from http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=POPC&Code1=1392&Geo2=PR&Code2=62&Data=Count&SearchText=Cambridge%20Bay&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=1392&TABID=1 [accessed 29 March 2018].

Uyguner, C.S., Bekbolet, M., and Swiétlik, J. 2007. Natural organic matter: Definitions and characterization. In Advances in control of disinfection by-products. Nikolau, A., Selcuk, H., and Rizzo, L. (eds.), Nova Science Publishers Inc., New York. pp. 419–446. Available from https://www.researchgate.net/profile/Ceyda_Uyguner_Demirel/publication/286329976_Natural_organic_matter_Definitions_and_characterization/links/566ebcba08aea0892c52a5df/Natural-organic-matter-Definitions-and-characterization.pdf [accessed 25 April 2018].