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ENVIRONMENTAL CHEMISTRY, POLLUTION & WASTE MANAGEMENT | REVIEW ARTICLE

# First Nations wastewater treatment systems in Canada: Challenges and opportunities

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**Abstract:** The Government of Canada has prioritized the availability of water and wastewater services for the Canadian First Nations Communities (CFNC) and introduced the First Nations Water and Wastewater Action Plan. Several studies explore that many wastewater treatment systems (WWTS) in the CFNC do not meet the effluent discharge limits. The objectives of this study were to examine the existing WWTS in CFNC, investigate the progress and improvement opportunities, evaluate the risk levels, encapsulate the financial condition, and provide recommendations for the overall improvement of the WWTS in CFNC. The authors found significant improvement in 2011 when 98% of the Canadian First Nations houses received wastewater services in comparison to only 50% in 1978. However, 1,777 First Nations houses did not receive any wastewater services. In 2011, 21% of the wastewater systems were operated exceeding the facilities' design capacities. The overall high-risk and medium-risk wastewater systems have reduced from 14 and 51% in 2011

## ABOUT THE AUTHORS

Mofizul Islam is a master's student in the CREATE H2O program, which is designed to address the research and training gaps of the Canadian First Nations' water and sanitation security, under the supervision of Qiuyan Yuan, an assistant professor at the University of Manitoba. Yuan's research goals include development of sustainable technologies for water and waste treatment processes. Her research team unravels a variety of environmental engineering topics including nutrient removal and recovery, landfill leachate treatment, biomass fermentation, and anaerobic digestion. Mofizul Islam's research is focused on improving biological treatment efficiencies of landfill leachate using selected fungal strains, which produce and secrete enzymes, to degrade complex structure of recalcitrant compounds of leachate. Since CREATE H2O program is the first science engineering research training program working towards the improvement of Canadian First Nations communities, researchers and especially the First Nations community personnel would like to access the knowledge and research gaps from this article to mitigate the issues related to the wastewater treatment facilities.

## PUBLIC INTEREST STATEMENT

Canadian First Nations Communities (CFNC) are facing greater challenges to reduce the high and medium risk level wastewater treatment systems. The severe lack of research in this area makes it harder to understand the real scenario. This leads the authors to compile the available information to get a clear overall scenario of the WWTS in CFNC. It was explored that 1,777 houses did not receive any wastewater services in 2011. According to the latest survey in 2014–2015, 6% wastewater systems were identified as high-risk level. The most concerning figure was related to the medium-risk level systems (41%). It is concluded that more funding is required to eliminate or reduce the high and medium risk level systems. The information from this article would be useful to the government and non-government agencies, policy-makers, CFNCs, and researchers for the future programs and policies related to WWTS.

to 6 and 41% in 2014–2015, respectively. The Government of Canada committed to provide $4.2 billion for the 10-year period (2011–2021) against the estimated cost of $6.3 billion. Increasing and proper utilization of the allocated budget is recommended to fill up the financial gaps.

**Subjects: Environmental Management; Environment & Economics; Environmental Change & Pollution**

**Keywords: sanitary system; First Nations; wastewater treatment systems; wastewater lagoon; risk level**

## 1. Introduction

The Government of Canada is committed to ensure that the wastewater treatment systems (WWTS) in Canadian First Nations Communities (CFNC) are safe, meet the community necessities with appropriate monitoring systems, and also meet the federal and provincial effluent discharge limits (Government of Canada, 2016). Efficient and effective wastewater management process has become not only a concern but also an emerging challenge for the CFNC due to the lack of resources, remoteness, and extreme northern climate condition. The assessment report, published in 2003, of Indigenous and Northern Affairs Canada (INAC) (previously referred to as Aboriginal Affairs and Northern Development Canada) by the Department of Indian Affairs and Northern Development (DIAND) identified six major deficiency areas of WWTS in CFNC: treatment technology design, operation and maintenance, operator skills and knowledge levels, monitoring system, dysfunctional equipment, and protecting the receiving watershed (INAC, 2003). The additional major challenges are the availability of equipment and supplies, high operator turnover rate, and economic constraint (Mallett, 2010).

CFNC receive wastewater treatment services through centralized and decentralized wastewater systems. Centralized system is a communal WWTS in which wastewater is transported to a central treatment facility, for example, wastewater stabilization lagoon and activated sludge plant, by collecting through a piped collector system. On the other hand, decentralized system is an on-site WWTS, for instance septic system, managed by a group or groups of Band Councils. Providing wastewater treatment services to the CFNC in a centralized system is a shared responsibility among the First Nations' Band Councils, Environment and Climate Change Canada (previously known as Environment Canada), Health Canada, and INAC (INAC, 2016; Simeone, 2010). The Band Council is responsible for 20% of financial costs as well as ensuring the proper design, construction, operation, and maintenance of WWTS following the more stringent federal and provincial government standards (INAC, 2010a; White, Murphy, & Spence, 2012). They are also accountable for organizing training sessions to ensure that the operators are properly trained and certified (Heinke, Smith, & Finch, 1991; INAC, 2010a). Environment and Climate Change Canada regulates the wastewater effluent discharge into the receiving watershed and is also accountable for providing advice and technical expertise (AANDC, 2012a; INAC, 2016; Simeone, 2010). Environmental and public health assessment, plant inspections, responding to complaints, and planning reviews are under the job scope of Health Canada. In addition, mass people awareness programs such as community-based education pertaining to the wastewater issues are developed and communicated to the concerned communities by the Health Canada (AANDC, 2012b; Health Canada, 2016; White et al., 2012). INAC affords financial support for wastewater treatment facilities (i.e. 80% of design, construction, operation, and maintenance) along with staff (operator) training, setting standards, developing regulations to implement standards, and reviewing designs and facility performance in collaboration with Environment and Climate Change Canada (AANDC, 2012a; Simeone, 2010).

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The roles and responsibilities of First Nations, INAC, Environment Canada, and Health Canada in decentralized on-site WWTS are different from the centralized systems. Within the First Nations, the responsibilities of managing decentralized systems are divided between Band Councils and system operators. Band Councils are responsible to ensure that the wastewater systems are designed, constructed, and upgraded by following the Protocol for Decentralized Water and Wastewater Systems in First Nations Communities (INAC, 2010b). Systems operators are responsible for operating, maintaining, sampling, testing, monitoring, and keeping records. AANDC provides full or partial financial assistance and facilitates training. Environment Canada administrates and enforces the acts and regulations as well as provides information regarding the regulatory and environment protection requirements. On the request of individual resident, Health Canada may sample and test the wastewater in the close proximity but they do not have any obligatory sampling and testing requirements (INAC, 2010b).

The Government of Canada has set a goal for the WWTS in CFNC to meet the more stringent federal wastewater systems effluent regulations (White, Murphy, & Spence, 2012) and to address the concerns through the Canadian Environmental Sustainability Indicators (CESI) program under the Federal Sustainable Development Strategy (2013–2016).

Ontario Clean Water Agency (2001) stated in the assessment report prepared for the Shibogama First Nations Council that effluent discharge exceeded the *Escherichia coli (E. coli)* concentration to 12,500/100 ml (*E. coli* discharge limit for Ontario: 400/100 ml). The report also mentioned numerous reasons for the increase of *E. coli* in effluent such as overloading of the plant's capacity, equipment malfunctioning, overflowing, and floor flooding. This information presents challenges to the Canadian Government to achieve the commitment of mitigating First Nations needs of wastewater services and eventually necessitates a complete review of the WWTS in CFNC.

The objectives of this study were to: (1) summarize the literature and technical reports pertaining to WWTS in CFNC for the better understanding of the existing systems, (2) identify and track down the progress and improvement opportunities in accordance with the previous records, (3) evaluate the critical risk levels of different WWTS in CFNC, (4) do a comparison study between the actual investments by the Government of Canada and the estimated cost by the national assessment to meet the need of First Nations wastewater services as well as to fulfill the commitment undertaken by the Government of Canada, and finally (5) provide recommendations to address the current challenges and improvement opportunities.

## 2. First Nations wastewater treatment systems

Indian and Northern Affairs Canada (INAC) reported that there were 617 First Nations communities in Canada in 2014 (INAC, 2014). This number was about 570 in 2011, out of which only 418 First Nations communities received wastewater services from the 532 treatment systems (Neegan Burnside, 2011i) in the form of wastewater stabilization lagoons (aerated and facultative lagoons), mechanical treatment plants, Municipal Type Agreements (MTA), and individual septic systems (INAC, 2003; Neegan Burnside, 2011i). The wastewater system has been defined as "an organized process and associated structures for collecting, treating, and disposing of wastewater", which was specified as a system serving five or more houses for the purposes of the national assessment report (Neegan Burnside, 2011i). The number of wastewater systems and the corresponding percentages in terms of the relative significance of each WWTS used in CFNC have been captured in Figure 1.

According to the national assessment of Neegan Burnside (2011i), there were a total of 484,321 on-reserve First Nations' population residing in 112,836 houses with an average of 4.3 persons per household. Sixty-three percent of the dwellings were served by the communal wastewater systems. Many CFNC receive wastewater treatment services from the neighboring municipalities, First Nations,

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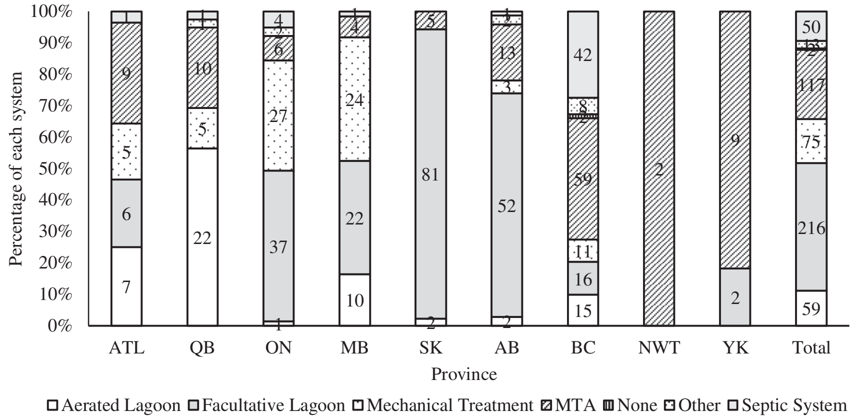
**Figure 1. The overall categorization of the WWTS in CFNC.**

Notes: The value inside the bar indicates the number of WWTS and the height of each bar represents the corresponding relative percentage of that system in comparison with the total systems. Data adapted from Neegan Burnside (2011i).




or other private sectors through the MTA (FCM, 2011; INAC, 2003). MTAs were used as a servicing arrangement for 22% of WWTS in 2011.

Different types of WWTS that are implemented in CFNC are described in the following sections and the relevant concerns related to a particular WWTS are also highlighted.

### 3.1. Wastewater stabilization Lagoon

Wastewater treatment in the lagoon is performed in an engineered constructed wetland or a pond with a preventive measure of avoiding liquid drainage into the ground water or to the surrounding fields (Spellman & Drinan, 2014). Both aerobic and anaerobic decomposition of waste matter occurs naturally in the lagoon without any mechanical equipment (aeration) and it is commonly known as a facultative lagoon. Some lagoons have been designed with the provision of mechanical aeration systems known as an aerated lagoon, which facilitates higher depth of the lagoon cells for the same level of treatment performance as a facultative lagoon, and results in a smaller footprint (Spellman & Drinan, 2014). Lagoon provides both treatment and storage facilities of wastewater, sludge, and other contaminants. Wastewater treatment proceeds through a series of physical (UV radiation, settling, and mixing), chemical (precipitation and nutrients reaction), and biological processes (algal and bacterial activity) (Spellman & Drinan, 2014), which removes contaminants from the wastewater.

Wastewater stabilization lagoon is the most commonly used centralized WWTS in CFNC to treat sewage wastes reported in the national assessments (INAC, 2003; Neegan Burnside, 2011i). More than 50% of the WWTS in CFNC are lagoon based, whereas 11% are aerated lagoons and 41% are facultative lagoon systems (Figure 1). The First Nations communities of Alberta (72%) and Saskatchewan (92%) mostly use facultative lagoons following the province of Ontario (48%). On the other hand, aerated lagoons are highly used in Quebec (56%).

Although the lagoon-based WWTS are suitable for the small communities of First Nations, some serious health and environmental issues have emerged due to the lack of resources, proper operations, and monitoring or site selection. For instance, nutrient pulses (Nitrogen and Phosphorus) exceeded its recommended threshold limit in the Dead Horse Creek, Manitoba, Canada during the discharge period (Carlson et al., 2013). The worst-case scenario was found in the Kashechewan reserve's First Nations community, where the Minister of Aboriginal Affairs, Ontario, had to evacuate 1,000 residents due to the high level of *E. coli* in the community's drinking water (Senate of Canada, 2007). According to the final reports of the Standing Senate Committee on Aboriginal Peoples (2007) and CBC News (2007), the main contamination source was identified as the poor-quality source water because of the installation of drinking water treatment plant downstream of the community's sewage stabilization lagoon. The national assessment report revealed that 18% of the wastewater stabilization ponds (both aerated and facultative lagoons) in CFNC have failed to meet the federal effluent discharge limits due to the lack of proper operation (Neegan Burnside, 2011i) and 24% aerated lagoons and 47% facultative lagoons do not have effluent discharge data (Figure 3).

To keep the nutrient discharge limits of unionized ammonia, total nitrogen, and phosphorous within the threshold limit in the extreme cold conditions, wastewater management strategies like constructed wetlands and/or natural wetlands (secondary treatment options) have been considered as a proven technology. On the other hand, some of the researchers have successfully restricted the nutrient discharge using limestone rock filters (Strang & Wareham, 2006), active slag filters (Pratt, Shilton, Pratt, Haverkamp, & Bolan, 2007), or some form of chemical treatment (for instance, the utilization of aluminum salts or iron salts such as alum, sodium aluminate, poly-aluminum chloride, ferric chloride, ferrous chloride, and ferrous sulfate) (US EPA, 2010) in the wastewater stabilization ponds.

### *3.2. Mechanical treatment plant*

Mechanical wastewater treatment plant, a centralized WWTS, for the CFNC is designed in small capacity range, which consists of the main treatment units of Rotating Biological Contactors (RBC), Sequencing Batch Reactors (SBR), Extended Aeration (EA), or Moving Bed Biofilm Reactor (MBBR) (Pictou Landing First Nation, 2012). Most of the mechanical treatment plants are designed with the provision of aeration and agitation arrangement, in addition to a preliminary treatment (screening, grit removal) unit and a final stabilization-disinfection process such as a sand filter or UV disinfection (Neegan Burnside, 2011i). Mechanical treatment plants are not very common in the CFNC due to the small community size, complexity in operation and maintenance, and community remoteness. In Canada, among the 532 WWTS in CFNC, 14% are mechanically designed treatment units, while Manitoba and Ontario have the highest percentages of 40% and 35% mechanical WWTS, respectively (Figure 1).

Table 1 exhibits that CFNC have 75 mechanical WWTS, 20 systems of which have not been categorized and are thus mentioned as Mechanical (unidentified) in the National Assessment report published in 2011.

#### *3.2.1. Rotating biological contactor (RBC)*

The RBCs are considered as the mechanical treatment plants and are designed to accelerate the natural biological wastewater treatment process by facilitating the growth and accumulation of micro-organisms on the surface of the rotating contactor disk. The report from the Assembly of First Nations (2008) expressed that 15% of the total WWTS in CFNC in the province of Ontario had the technological basis of RBC or SBR in 2005, which increased to 26% in 2011 (Neegan Burnside, 2011e). As shown in Table 1, the First Nations in the province of Ontario have the highest number of RBC systems (18 out of 27 RBC systems, 67% of Canadian First Nations' RBC systems and entire

**Table 1. Number of mechanical WWTS in CFNC (Neegan Burnside, 2011a–2011f)**

| Treatment type/Region | BC | AB | AT | MB | ON | QB | Total | Percentage (%) |
|---|---|---|---|---|---|---|---|---|
| RBC | 5 | 1 | | | 18 | 3 | 27 | 36 |
| SBR | 2 | 1 | | 18 | 2 | | 23 | 31 |
| Activated sludge plant | 2 | | | | 1 | | 3 | 4 |
| Trickling filter plant | | 1 | | 1 | | | 2 | 3 |
| Mechanical (unidentified) | 2 | | 5 | 5 | 6 | 2 | 20 | 27 |
| Total | 11 | 3 | 5 | 24 | 27 | 5 | 75 | |

Notes: BC : British Columbia, AB: Alberta, AT: Atlantic Provinces (Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland and Labrador), MB: Manitoba, ON: Ontario, QB: Quebec, RBC: Rotating Biological Contactor, SBR: Sequencing Batch Reactor.

province's mechanical systems) as compared to other regions. Nationally, among the total mechanical WWTS in CFNC, RBC-based systems are used the most at 36% (27 out of the total of 75 systems).

#### *3.2.2. Sequencing batch reactor (SBR)*
SBR is another form of mechanical treatment plant, which is designed based on the modification of the conventional activated sludge process. According to the Manitoba regional roll-up report of INAC prepared by Neegan Burnside (2011d), there are 18 SBR WWTS (30% of the total systems) in the Manitoban First Nations communities, which is the highest number across all other Canadian provinces of First Nations' SBR systems. SBR is the second highest technologically used system, accruing 31% of all mechanical systems, following RBC in CFNC (Table 1).

#### *3.3.3. Activated sludge plant*
Activated sludge plant is the conventional WWTS having the secondary treatment options and more economical for a large community. There are a total of three activated sludge wastewater treatment plants in the CFNC, one of them is in the province of Ontario (Independent First Nations' community) and other two are in British Columbia (Beecher Bay and Nanoose First Nations' community), where the community population size is very large (Table 1).

#### *3.3.4. Trickling filter plant*
Trickling filter plant is a type of mechanical treatment system that consists of a fixed bed (rocks, coke, gravel, slag, polyurethane foam, ceramic, or plastic media) where the wastewater flows downward over the bed and causes growth of a layer of biofilm (microbial slime) to cover the bed of media. Trickling filters are used for the treatment of very small rural sewage systems. In the CFNC, there are only two WWTS based on this technology, one is in Manitoba (Brokenhead First Nations' community), and other one is in Alberta (Stoney Nakoda Tribal Nation).

#### *3.3.5. Moving bed biofilm reactor (MBBR)*
An MBBR is a relatively new mechanical wastewater treatment technology in the CFNC. Biofilm, biofilter, and activated sludge processes have been integrated together to design an MBBR system that enables the entire reactor volume for biomass growth (Rusten, Eikebrokk, Ulgenes, & Lygren, 2006; Tomaszek & Koszelnik, 2015). Recently, God's Lake First Nations community in Manitoba had planned to set up an MBBR system and had placed an invitation to tender for the community's sewage treatment plant (God's Lake First Nations's, 2013).

### ***3.4. Septic systems***
Septic system, a decentralized WWTS, is used to treat small-scale sewer wastes for an individual or a small group of houses. In the national assessment report, Neegan Burnside (2011i) mentioned that 153 First Nations communities, which contain about 40,800 houses (36% of total First Nations homes), have individual septic systems in Canada. Nationally, 9% wastewater systems (50 of 532 systems) are based on septic systems in CFNC. The First Nations communities in British Columbia have the highest number of septic systems at 27% (42 of 153 systems) (Figure 1). A serious health and environmental concern has surfaced that accounted for about 20% of the systems discharging septic wastes directly into the ground surface and the higher rates of 40 and 42% were recorded in Alberta and Saskatchewan, respectively. The assessment also showed that nationally 47% septic systems had operational concerns of limited maintenance, aging of the systems, not pumping out septage waste on a regular basis, and inappropriate leaching bed. The maximum operational concerns, associated with over 60% of the septic systems, were recorded in Manitoba, Saskatchewan, and Alberta (Neegan Burnside, 2011i).

## 4. Evolution of wastewater treatment systems in Canadian First Nations communities
An improvement is noticeable for the essential sewer and wastewater services received by First Nations communities in the past 30 years. For instance, in 1978, almost 50% on-reserve First Nations

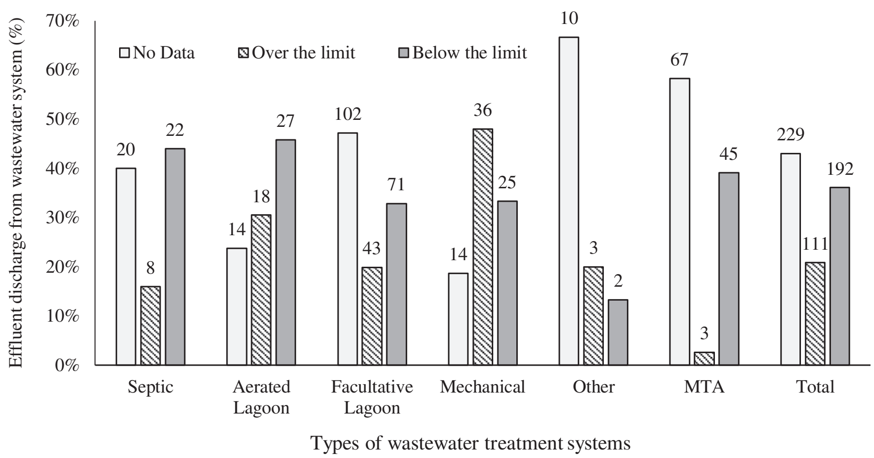



**Figure 2. The effluent quality data of wastewater treatment systems in First Nations' of Canada.**

Notes: The value above the bar represents the corresponding number of wastewater treatment systems. Data adapted from Neegan Burnside (2011a–2011h).

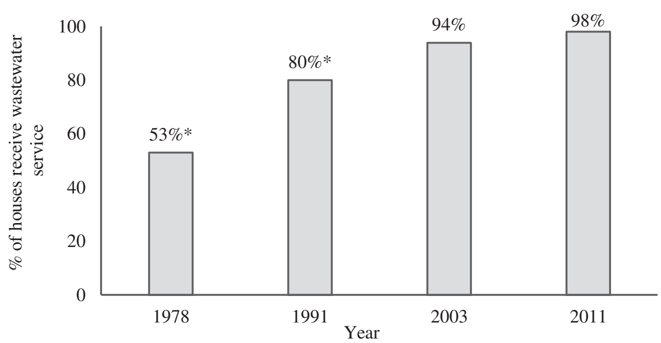



**Figure 3. Progressive trend of wastewater services in the CFNC in last 30 years.**

Notes: Adapted from Canadian Encyclopedia (2015), INAC (2003) and Neegan Burnside (2011i).*Based on the number of First Nations' houses on reserve that received minimum water and wastewater services.

houses did not have any water and wastewater facilities; whereas, in 2011, 98% CFNC received wastewater services by sewage pipe, truck-haul, or an individual septic system (Figure 2). Although the progress is perceptible, still 2% of First Nations homes that comprises of 1,777 houses in Canada do not have any wastewater services at all. The report also mentioned that 21% of the First Nations wastewater systems (113 systems) provided service at or exceeding the facilities' design capacities (Neegan Burnside, 2011i). The assessment also stated that 5% of the First Nations homes in the province of Manitoba do not have minimum wastewater services, which is the highest among the all Canadian provinces (Neegan Burnside, 2011d).

The regional reports of Neegan Burnside (2011a–2011g) showed that 21% of all WWTS in CFNC exceed the federal effluent discharge limits of either biological oxygen demand (BOD), total suspended solids (TSS), or total fecal coliform (Figure 3) in 2011, which was almost the same as reported by the first national assessment in 2003 of 22% wastewater systems exceeding the effluent discharge guideline (INAC, 2003). The most recent data show that this figure is about 23% in 2014–2015 (AANDC, 2015). Therefore, the discharge limits of several effluents have not been regulated since 2003 and require concrete actions. The matter of more concern is that nationally about 45% wastewater systems do not have any effluent discharge data (Figure 3).

Quebec and Saskatchewan possessed the most vulnerable WWTS in terms of exceeding the effluent discharge limits (41 and 35%, respectively). On the other hand, Alberta, Atlantic, Yukon, and Ontario had the highest number of wastewater systems without any effluent discharge data, which were 88, 64, 55, and 51%, respectively. The new Wastewater System Effluent Regulations, announced in July 2012, were designed to address this gap of exceeding effluent discharge limits and obligatory requirements of keeping discharge data records (Minister of Justice, 2016).

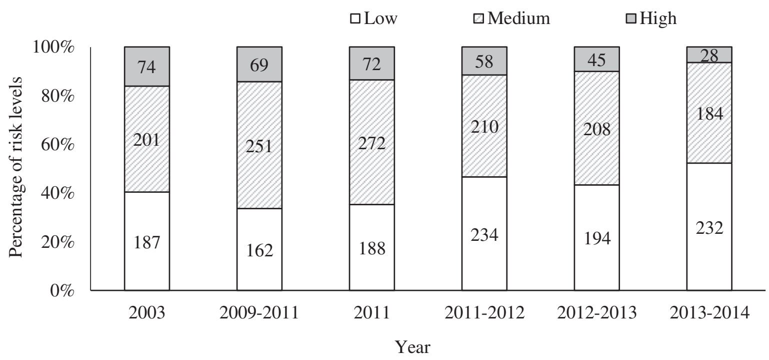



**Figure 4. Trend of overall risk levels of WWTS in CFNC over the last 12 years since the first national assessment in 2003.**

Notes: The value inside the bar represents the corresponding number of wastewater systems and the height of each bar represents the corresponding relative percentage at that risk level. Data adapted from ECCC (2016), INAC (2003) and Neegan Burnside (2011i). The number of lowrisk systems in 2014–2015 is 216, and medium- and high-risk systems data are not publicly available.

## 5. Evaluation of the risk levels of wastewater treatment systems in Canadian First Nations communities

According to the INAC Risk Level Evaluation Guidelines, the risk levels of WWTS in CFNC have been classified into three categories based on a scale of 1 to 10; low risk (1.0–4.0): systems having no problem or negligible minimal deficiencies, medium risk (4.1–7.0): systems requiring some repairs, and high risk (7.1–10): systems having potential health and safety issues. The overall risk of the system resides on five elemental weighing risks of effluent discharge (20%), system design (25%), operations (25%), reporting (10%), and operators (20%) of the respective wastewater treatment facility (INAC, 2011).

Recently, Environment and Climate Change Canada (ECCC, 2016) published a report of latest risk level scenario showing the improvement of WWTS in CFNC and indicated that high- and medium-risk systems have reduced from 14 and 51% of 2011 to 6 and 41% in 2013–2014, respectively.

The operational capacities of the First Nations WWTS have been depicted in the last assessment by Neegan Burnside (2011d, 2011i) that identified about 20% wastewater systems (113 systems) operating at or above the design capacity. Likewise, almost 40% wastewater systems of Saskatchewan (33 systems) and Alberta (27 systems) are operating in that concerned capacity range.

In 2003, nationally 16% (74 out of 462 systems) of the assessed systems were categorized as high risk, which needed immediate action to minimize potential health and safety concerns. The overall high-risk systems were slightly reduced to 14% (72 of 532 systems) in 2011. Moreover, the latest published data from the Environment and Climate Change Canada (ECCC, 2016) indicate a reduction in the high-risk systems to 6% of wastewater systems (28 out of 444 systems) in 2013–2014 (Figure 4). Ontario and Atlantic regions were more susceptible as a greater percentage of high-risk wastewater systems of about 36 and 25% were found in 2003 and 2011, respectively (Neegan Burnside, 2011i).

Although the percentage of high-risk WWTS in CFNC is in downward trend over the assessment period, the medium-risk level systems, which require certain improvements or system repairs, were increased from 44% (201 of 462 systems in 2003) to 51% (272 of 532 systems in 2011) (Figure 4). During the periods of 2011–2014, the medium-risk system was over 40%, which has slightly increased to 41% (184 of 444 systems) in 2013–2014. Alarmingly, more than 60% of the wastewater systems in the province of Alberta, Manitoba, and Quebec (60, 62, and 67%, respectively) have been categorized under the medium-risk level according to the National Assessment in 2011.

Despite the upward trend (increase from 40 to 52% between 2003 and 2013–2014) of the percentage of the low-risk systems in the national figure, the lowest value of 34% was found in 2009–2011 (Figure 4) and there were only 14 and 15% low-risk systems in Ontario and Quebec regions in 2011, respectively (Neegan Burnside, 2011i).

INAC developed four zones dividing the geographic areas of the First Nations communities based on the location and remoteness of the wastewater systems: Zone 1: First Nations located within 50 km of the service center with year-round road access, Zone 2: located between 50 km and 350 km of the service center with year-round road access, Zone 3: located over 350 km of the service center with year-round road access, and Zone 4: have no year-round road access to the service center.

The high-risk level is more prominent to the systems located in remote area and overall WWTS risks have increased with remoteness from 12% of the most readily accessible systems (Zone 1) to 29% of the least accessible systems (Zone 4). The reason could be the high transportation costs and unavailability of the resources. Number of people living in Zone 2 is much higher than any other zones where the high- and medium-risk systems are significantly greater than the low-risk systems. Although the medium-risk systems are almost evenly distributed among the zones, the number of medium-risks systems is almost half of the total systems (Table 2) in all zones. Similarly, 51% operators of WWTS had proper certification in the Zone 1, whereas only 27% operators of treatment systems were certified in Zone 4 (Neegan Burnside, 2011i).

## 6. Comparison of invested estimated cost for improving wastewater treatment systems

Although the main focus of this study was concentrated on First Nations wastewater services, a comparison study has been conducted between the actual investment and the estimated cost requirements. All the financial investment is pooled together for treating water and wastewater systems. There is lack of financial data solely for the WWTS (separated from water treatment system) in CFNC. Therefore, the related data of both water and wastewater systems have been considered from the previous assessments for the evaluation of invested amount and estimated costs, which include cost to upgrade existing systems to meet INAC's protocols, regulations, and federal and provincial standards and guidelines.

### *6.1. Investments by the Government of Canada*

During the tenure of 1995 to 2003, the federal government provided $1.9 billion for the maintenance of water and wastewater services of the CFNC. Following the confirmation of significant risk to the quality and safety of drinking water of three-quarters of the First Nations systems (Auditor General of Canada, 2005), the Government of Canada considered First Nations water systems as a priority and approved $600 million in 2003 over the five-year period until 2008. This money was reserved for the improvement and repair of the water and wastewater systems under the First Nations Water Management Strategy (FNWMS), in addition to the regular annual departmental allocation of about

**Table 2. First Nations' population, number of WWTS and percentage of systems at corresponding risk levels based on the four geographic zones**

| Zone | Population | No. of systems | High (%) | Medium (%) | Low (%) |
|---|---|---|---|---|---|
| Zone 1 | 95,212 | 177 | 12 | 44 | 44 |
| Zone 2 | 127,587 | 238 | 9 | 56 | 35 |
| Zone 3 | 13,558 | 24 | 4 | 58 | 38 |
| Zone 4 | 68,522 | 93 | 29 | 57 | 14 |
| Total | 304,879 | 532 | 14 | 51 | 35 |

$200 million until 2016. In 2006, INAC secured $60 million from the previous budget and made it available over two years to achieve the goal of Plan of Action for the Drinking Water for the First Nations Community (INAC, 2007). In 2008, the FNWMS was reshaped to First Nations Water and Wastewater Action Plan (FNWWAP) and implemented the proposed action plan of INAC (2007).

Since 2008, the Government of Canada has approved $330 million over two years of four consecutive terms (about $165 million per year) until 2016 for the on-reserve First Nations water and wastewater systems' installation, operation, and maintenance through the FNWWAP. To complete the First Nations ongoing water and wastewater infrastructure, Canada's Economic Action Plan (CEAP) approved additional $165 million in 2009 budget for two years (INAC, 2015). In the budget of 2016, the Government of Canada approved $141.7 million for monitoring on-reserve water and $1.8 billion for construction, repair, and improvement of the on-reserve water and wastewater infrastructure over the next five years (2016–2021) (Department of Finance, 2016).

Overall, during the 10-year period from 2010–2011 to 2020–2021, the government of Canada has committed to providing about $4.2 billion (through the regular annual departmental allocation, FNWWAP, CEAP, and budget for 2016) for the Canadian First Nations' water and wastewater services.

### *6.2. Estimated costs by the national assessment*

The national assessment report of INAC (2003) stated that there is a requirement of an estimated capital cost of $475–560 million to rectify the existing deficiencies, $185 million to address the backlogs, and $500 million to make water and wastewater services available to new houses Moreover, an additional $500 million is required to enrich the operational and maintenance practices, wastewater monitoring, proper training and education, developing standards, raising awareness, and to make emergency plans available in place. The estimated total cost was $ 1.7–1.8 billion over the five-year period (2003–2008) for the remedial action proposed by INAC (2003), which was almost equivalent to the total invested amount (about $1.7 billion) from the Government of Canada during the fiscal year of 2003–2008.

In the assessment report of Neegan Burnside (2011i), an estimate of $1.2 billion was claimed for the improvement of the existing systems, $4.7 billion for the recommended new servicing, and $419 million for the recommended operational and maintenance cost, which comprised a total of $6.3 billion over the 10-year period (2011–2021).

## 7. Recommendations: Challenges and opportunities

There are no publicly available data since the National Assessment (2011) report compiled by INAC, except for some partial information of the First Nations' wastewater risk levels data presented in the INAC departmental progress report. Therefore, to describe the First Nations' technological use, challenges to meet effluent discharge limits, zone-wise risk-level data, percentage of people receiving wastewater services, and many other vital issues have been presented in this review study based on the six-year-old data, and the recommendations are made based on the available information.

There are many operational and environmental concerns (for instance houses having no wastewater services, increase in septage surface discharge and effluent discharge guidelines, etc.) that have surfaced from the improper functioning of the WWTS in the CFNC, which were not well illustrated in the First Nations Water and Wastewater Action Plan (FNWWAP) (INAC, 2015); for example, occurrence of ground water contamination from leakage/drainage of liquids from lagoon, or the septic tank, or leaching bed drainage (Yates, 1985). These matters demonstrate the lack of available literature for the WWTS in CFNC, which are required for better understanding and to fix the flaws in the existing WWTS to minimize the health and environmental hazards to the First Nations people. Additionally, the regional roll-up reports of Neegan Burnside (2011a–2011i) also indicated that overall 45% systems did not have effluent discharge data and a few of the provinces did not have a record of any effluent discharge data at all. Therefore, it is highly recommended to monitor the

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discharged effluent limit to meet the INAC protocols and other federal and provincial regulations, and to instigate the researchers from the governmental organizations, corporate institutions, and university professors to overcome the difficulties faced by the CFNC.

The assessment report of Neegan Burnside (2011i) clearly specified that among the First Nations homes that were surveyed, 51% wastewater systems were identified at a medium overall risk, and most importantly 14% wastewater systems were classified at a high overall risk. Therefore, the objectives of the national assessment of INAC (2003) were not met at the end of the five-year period in 2008, despite the allocation of $1.7 billion, which expresses the concern of either the incompleteness of the national assessment or the improper utilization (financial mismanagement) of the allocated funds towards the First Nations water and wastewater systems. Moreover, the amount of $4.2 billion declared in the Budget of 2016 (Department of Finance, 2016) to meet the FNWWAP for the 10-year period (2011–2021), is still lacking $2.1 billion from the estimated cost of $6.3 billion (Neegan Burnside, 2011i). For this reason, continuous tracking of the financial investment released along with the actual progress to meet the objective of the INAC protocol is very crucial and therefore, it is advisable to increase the budget as well as to concentrate more on proper utilization of the allocated budget to achieve the initial commitment of the Government of Canada. Furthermore, regular assessment of the risk level of the systems is recommended for the thorough evaluation of the First Nations wastewater systems.

Wastewater stabilization ponds are the most commonly used systems in CFNC. However, several incidents have indicated that nutrients' (Nitrogen and Phosphorus) concentration in the discharge effluent of sewer lagoons exceeded the threshold limit of effluent discharge set by Environment Canada. Hence, implementation of wastewater management strategies like constructed wetlands (where possible) or natural wetlands are advisable, which prevents releasing the sewer lagoon effluent directly to the fresh source water or lake to minimize the nutrient loads. Moreover, to keep the nutrient discharge (unionized ammonia, nitrogen, phosphorous) within the threshold in the effluent discharge of the wastewater stabilization ponds in CFNC, it is advised to perform the feasibility study of using limestone rock filters, active slag filters, or some form of chemical treatment (aluminum or iron salts).

## 8. Conclusion

The risks level of First Nations water and wastewater systems greatly affect Canada's performance on key environmental sustainability issues and are considered as a part of the Canadian Environmental Sustainability Indicators (CESI) program. The risk-level indicator helps measure the progress toward the goals of the Federal Sustainable Development Strategy (2013–2016). From this study, it is concluded that since the commencement of national assessment on First Nations water and wastewater systems, an improvement is noticeable in First Nations wastewater systems. However, there are many First Nations houses that do not have minimum wastewater treatment services and many WWTS neither meet effluent discharge limits nor have effluent discharge records, which has become a serious health and environmental concern. High-risk wastewater systems have considerably reduced but the medium-risk systems have risen in numbers. The environmental concerns associated with these systems diminish the positive sign for Canada's performance on key environmental sustainability issues. Therefore, more funding would be required on a provincial and a federal level to meet the government's goal to continuously improve the wastewater treatment facilities of First Nations communities. Although the study is focused on the WWTS in CFNC, the findings and recommendations could also be applicable for the remote small communities outside of Canada where new wastewater regulations are implemented for the small and remote communities, changes in law that affect the communities' effluent discharge limits or bringing new programs and policies for the improvement of the small communities WWTS.

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