EXTENDED USE OF RAINWATER HARVESTING SYSTEMS (RWHS) IN NORTHERN CLIMATE: A CHALLENGE?

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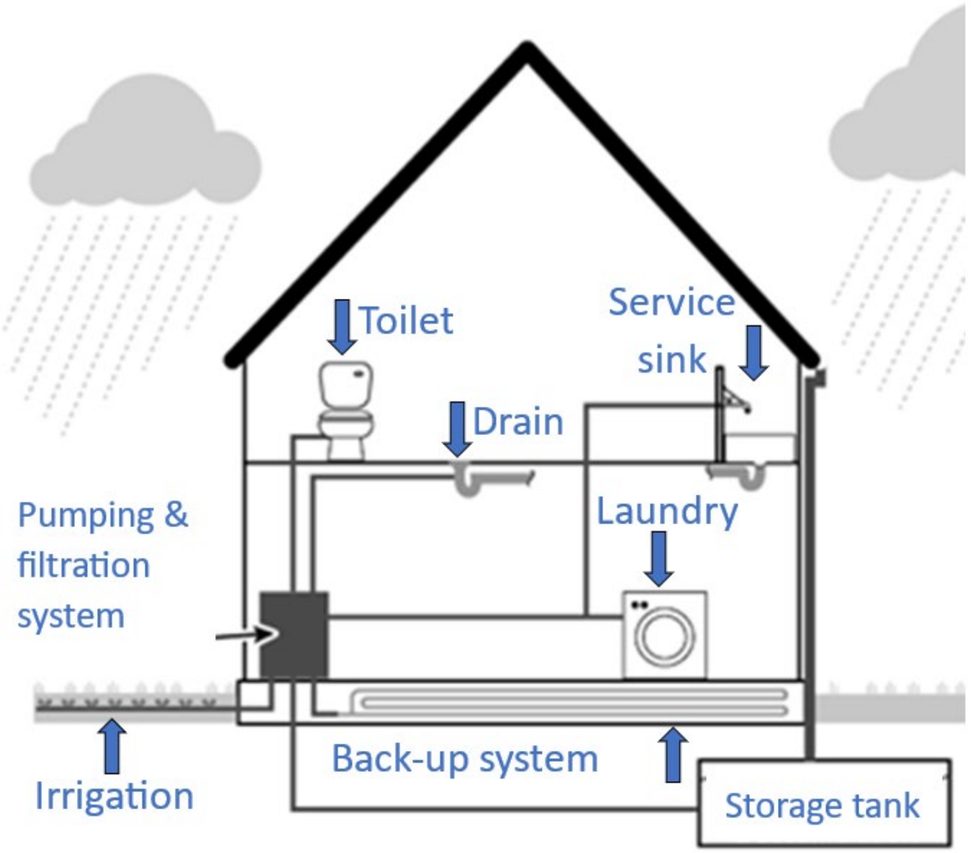
RAINWATER COLLECTION AND REUSE

- Rainwater harvesting system (RWHS) context
- Challenges
- National and international regulatory framework
- Water quality survey at large building system

INTRODUCTION TO RWHS

- An alternative water supply system
- A primary source of water for non-potable uses, such as gardening and toilet flushing
- 4 main components: collection surface, gutters to convey the water, storage tank and distribution system
- Stormwater runoff management
- Long-term ecological benefits



Adapted from RBQ 2022

MOTIVATION

The United Nations General Assembly launched the Water Action Decade in 2018 setting the Sustainable Development Goals (SDG) with a number of targets to be achieved by 2030:

- Target 6.3: to improve water quality, halve the proportion of untreated wastewater, and substantially increase recycling and safe reuse globally

- Target 13.1: to strengthen resilience and adaptive capacity to climate-related hazards in all countries (UN, 2020)

In Québec - Municipal Affairs and Housing (MAMH):

- Novel action plan encouraging adoption of RWHS → reduce of drinking water consumption **as part of** 2019 update in Québec Drinking Water Saving Strategy

POTENTIAL FOR CANADA

- 30% reduction in drinking water consumption for a 25-stories building located in Canada (Tokar et al., 2021)
- Economically viable alternative with a payback period of 20 years (Maskwa et al., 2021)
- Preventing restrictions on drinking water consumption during certain periods of the year
- Improved microbial rainwater quality in cold northern climate (Despins et al., 2009)
- Preventing stormwater sewer overflows in the case of heavy rain events (Petrucci et al., 2012)
- Great potential for meeting agricultural water needs

CHALLENGES

- Health risks associated with certain types of rainwater exposure
- Exclusive use of RWHSs for controlling runoff during heavy rainfall events
  - ➢ No intention of using the collected water, prolonged stagnation
- Dual plumbing system - accidental connections and backflow
- Prolonged stagnation in winter or risk of freezing for outdoor storage tanks
- No national policies and regulations for rainwater quality in Canada (Hindiyeh et al., 2021)
- Lack of public awareness and absence of supporting guides or training for installers and owners
- Uncertainty as to how the systems should be designed, constructed, operated, and maintained to ensure water quality

ROOF-HARVESTED RAINWATER QUALITY

PHYSICO-CHEMICAL → Correlation → **MICROBIOLOGICAL**

Temperature
Conductivity
pH
Turbidity
Alkalinity
Solids
Heavy metals

Debris, dusts

Enteric pathogens

Bacterial
Viral
Protozoan

Animal feces,
plants,
roof deposits

Opportunistic premise plumbing pathogens (OPPPs)

Legionella
Mycobacterium
Acanthamoeba

Biofilms

4 main microbial quality indicators (Verhille, 2013)

- Heterotrophic plate counts (HPC)
- Total coliform (TC)
- Fecal coliform (FC)
- *Escherichia coli* (*E. coli*)

HEALTH CONCERNS

- Occurrence of waterborne diseases
- Risk of direct consumption, skin contact, or inhalation of contaminated aerosols (*Legionella*), while using rainwater for outdoor applications or toilet flushing (Quon et al., 2021)
- Correlation with the targeted end use (De Man et al., 2014; Lim & Jiang, 2013)
- Mainly associated with microbial quality of water rather than physicochemical parameters BUT pH and heavy metals can impact microbial quality
- Two outbreaks of *Legionella* associated with exposure to harvested rainwater

FACTORS AFFECTING THE QUALITY OF ROOF-HARVESTED RAINWATER

SEASONAL FACTORS

- Microbial quality may or may not be associated with seasons, depending upon the type of organisms investigated and the climate in which RWHS is located.
- Temperature, total suspended solids, and heavy metals vary with seasons.

METEORLOGICAL FACTORS

- Rain is associated with the synoptic weather system and air masses that determine airborne bacterial communities in rainwater.
- Low temperatures inhibit bacterial growth (Despins et al., 2009).

SYSTEM DESIGN AND MAINTENANCE

The choice of treatment technologies, roofing materials, and the storage tank affect all physiochemical and microbiological parameters of harvested rainwater.

INTERNATIONAL REGULATORY PERMITTED USAGE

Canada	Australia	France
• Water closets and urinals • Clothes washers • Irrigation systems • Floor-mounted service sinks and laundry trays • Hydronic systems • Make-up water for heat rejection systems • Trap primers	• **Drinking water** • Garden watering • Toilet flushing • Laundry • Replenishing domestic pools or spas • Car washing • Supplying hot water systems • Thermal buffers to insulate houses • Ventilation for buildings • Protecting homes from bushfires	• Outdoor usage • Indoor usage for toilet flushing and ground washing • Indoor usage for laundry

INTERNATIONAL REGULATORY FRAMEWORKS DESIGN CONSIDERATIONS I

AUSTRALIA

PCA 2019
AS/NZS3500
Guidance on the use of rainwater tanks (enHealth)

- Clearing overhanging vegetation, leaf filters
- Calculating the catchment area, certain types of roofs are prohibited for drinking purposes
- Calculating the required tank capacity based on catchment area, expected rainfall, and intended uses
- First flush diverter for the first 20-25 L of water capture
- Ensuring the structural integrity of the tank including installation factors
- Preventing the entry of light into tanks or pipe work
- Reflux valve, self-sealing valve, backflow prevention devices to prevent rainwater from flowing back into the potable water supply

INTERNATIONAL REGULATORY FRAMEWORKS DESIGN CONSIDERATIONS I

FRANCE

National Order of August 28, 2008

- Inaccessible roof
- Storage tank protected against external pollution, easily and thoroughly cleanable, drainable with no residual stagnation, and inner walls made of inert materials
- Collection surface free of asbestos and lead, storage tank protected against severe temperature elevations, and a filtration process for the second category of end-use
- More advanced treatment for category 3 of end-use

NATIONAL REGULATORY FRAMEWORKS

CANADA

NR24-29-2020
CSA B805-18
ASHRAE Handbooks
ASPE Handbooks
ARCSA/ASPE/ANSI 63

- Inaccessible roof to vehicular and pedestrian traffic
- Dissolution-resistant roofing material with no leaching of harmful substances.
- Debris screen with a mesh size of not more than 6 mm
- First-flush diversion system with a capacity of not less than 0.3 L/m2 of roof area.
- Calming inlet or settling chamber ahead of the storage tank inlet
- A device to prevent the entrainment of sediment into the pump, and filter with a mesh size of not more than 50 µm where the harvested rainwater is used indoor
- Reducing valve, tank overflow to designated locations, backflow prevention for make-up water connections, and safeguards for fixtures combining non-potable and potable water

OTHER STANDARDS AND USEFUL DOCUMENTS IN CANADA

- Rainwater Harvesting Task Group. Ontario Guidelines for Residential Rainwater Harvesting Systems (2010)
- Rainwater Harvesting Task Group. Alberta Guidelines for Residential. Rainwater Harvesting Systems (2010)
- Canada Mortgage and Housing Corporation. Guidelines for residential rainwater harvesting systems, handbook (2012)
- Ministry of Health. British Columbia. Guidance for Treatment of Rainwater Harvested for Potable Use (2020)

CHARACTERIZATION OF RESIDENTIAL SYSTEMS

- 10 systems sampled (located in province of Québec)
- Installed between 2013 and 2022
- Roofing material included asphalt, steel, aluminum, cedar, PVC, vinyl
- Gutter material mainly aluminum and PVC
- 30% interior and exterior use
- 1/10 system had a 5 µm filtration unit
- 60% had debris in the water recovery system
- Reservoir capacity between 3,000 and 7,000 L

Premier Tech 2022

WATER QUALITY RESULTS

Physico-chemical:

- Turbidity > 5 NTU for 2/10 systems
- Low alkalinity 6 – 26 mg $CaCO_3$/L
- Metal concentration vary from one system to another – roof and gutter material impact?

Microbial:

- All systems had high levels of culturable bacteria in water (1,260 CFU/mL)
- Total coliforms varied between 3.6 and 1,800 CFU/mL
- Fecal coliforms detected up to 10/mL in 3/10 systems

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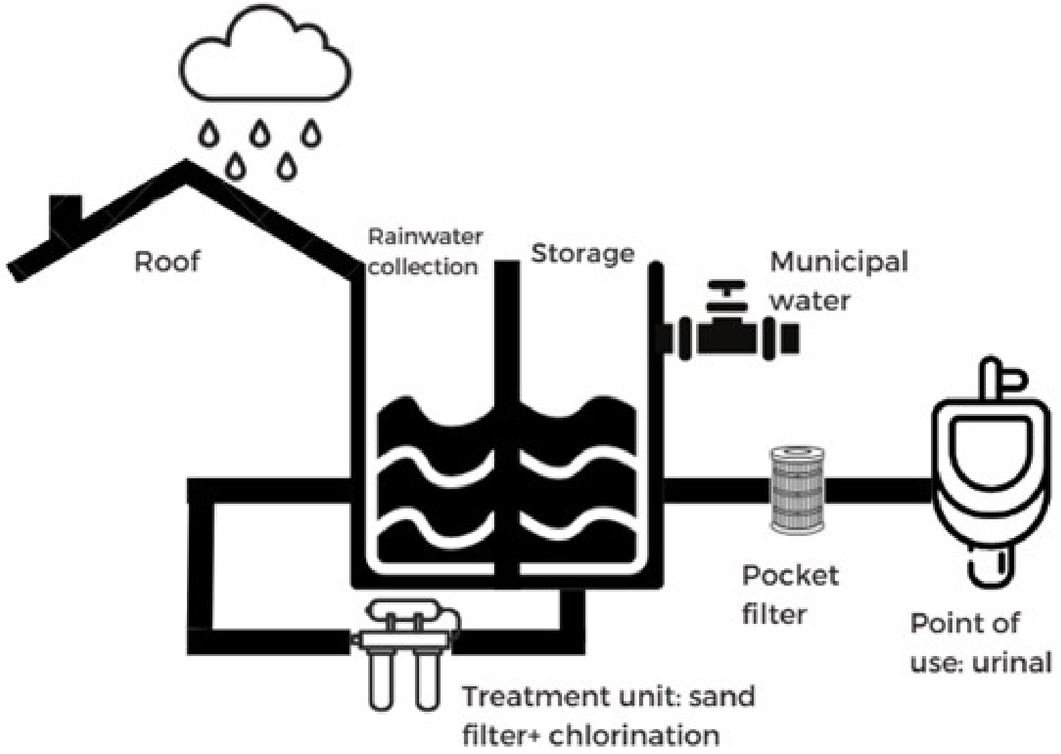
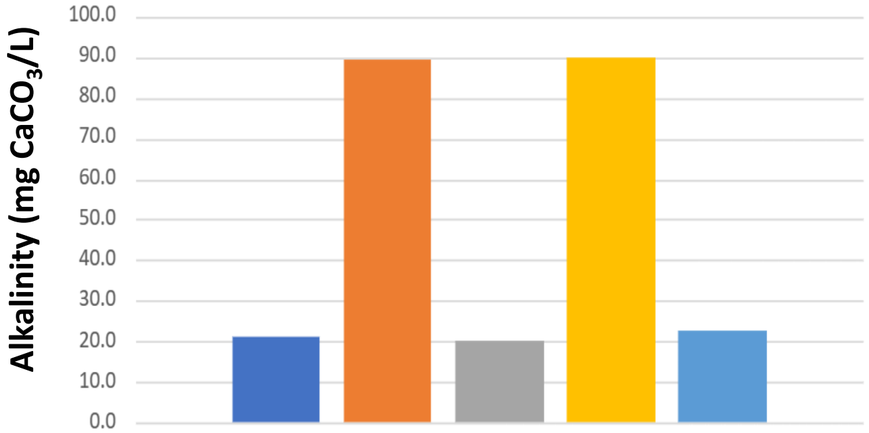
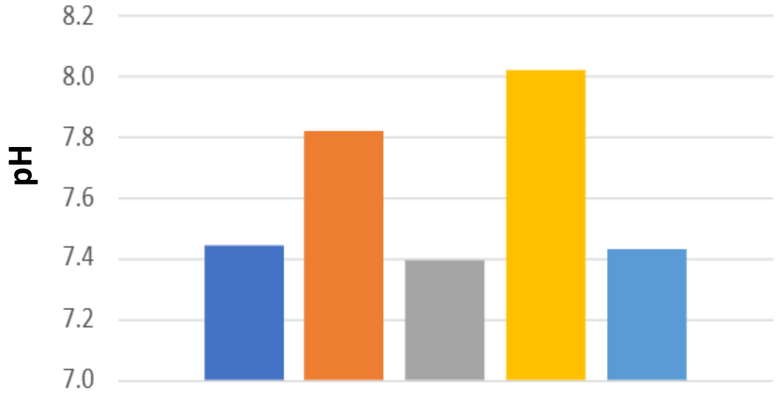
INVESTIGATION OF A LARGE BUILDING RWHS

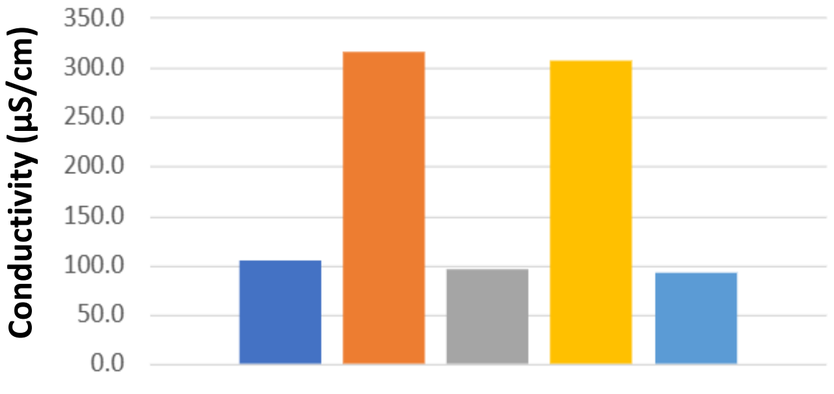


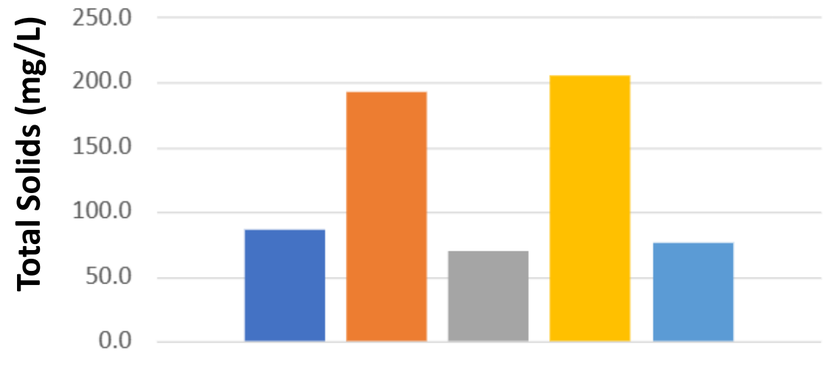
Schematic of a large building RWHS

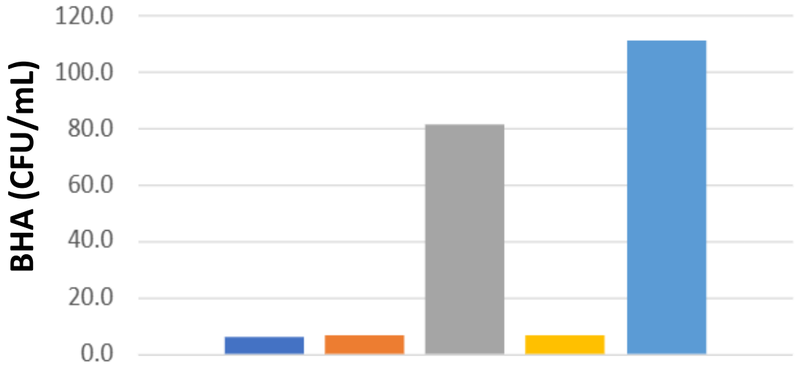
WATER QUALITY RESULTS
LARGE BUILDING RWHS











Urinary Tap Storage tank City water Filter

WATER QUALITY RESULTS LARGE BUILDING RWHS (2)

- The level of total chlorine at the point of use (0.09 mg/L) is lower than the CSA minimum (0.5 mg/L)
- The pH at the point of use (5.93) is lower than the CSA minimum (7)
  - Coliform growth
  - Rainwater corrosiveness in the presence of low alkalinity (Mazurkiewicz et al., 2022)
- BHA at the point of use exceeds CSA limit (500 CFU/100 mL)
- Presence of total coliform at the storage tank and filter

IMPORTANCE OF THE SYSTEM MAINTENANCE

- A study demonstrated that water quality is linked to the frequency of emptying and cleaning the tank (Lévesque et al ., 2008)
- Link between the frequency of tank cleaning and the presence of *E. coli* (102 tanks studied)
- Tanks that are not cleaned regularly could encourage the growth of *Legionella* in the biofilm (Simmons et al., 2008)
- Biofilm formation in tanks can protect and promote the development of pathogenic bacteria, leading to health risks (Schets et al., 2010)

INTERNATIONAL MAINTENANCE PRACTICES

City of Berkeley (2010)

- Inspection, cleaning, and replacement of filters and screens **every three months**
- Inspection of the roof, gutters, and downspouts **every six months**
- Inspection of pumps, valves, tanks, signage, and pipes marking once after initial installation and **every 12 months thereafter**
- Removing overhanging tree branches and vegetation **as needed**

Consideration of pathogen testing

- Texas Water Development Board (2005)

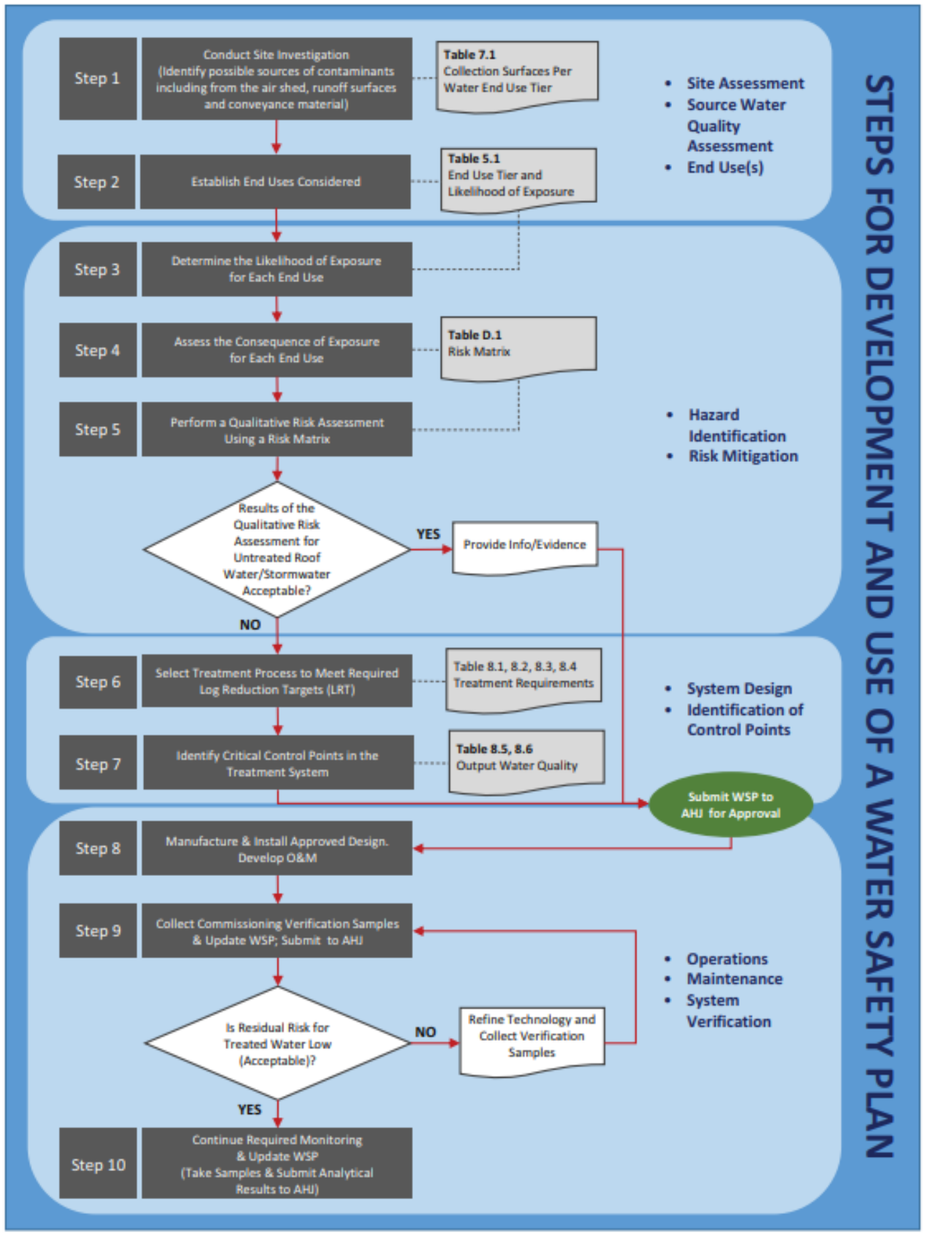
MAINTENANCE PRACTICES
NR24-29-2020 / CSA B805-18

NR24-29-2020 recommends the following preventive measures:

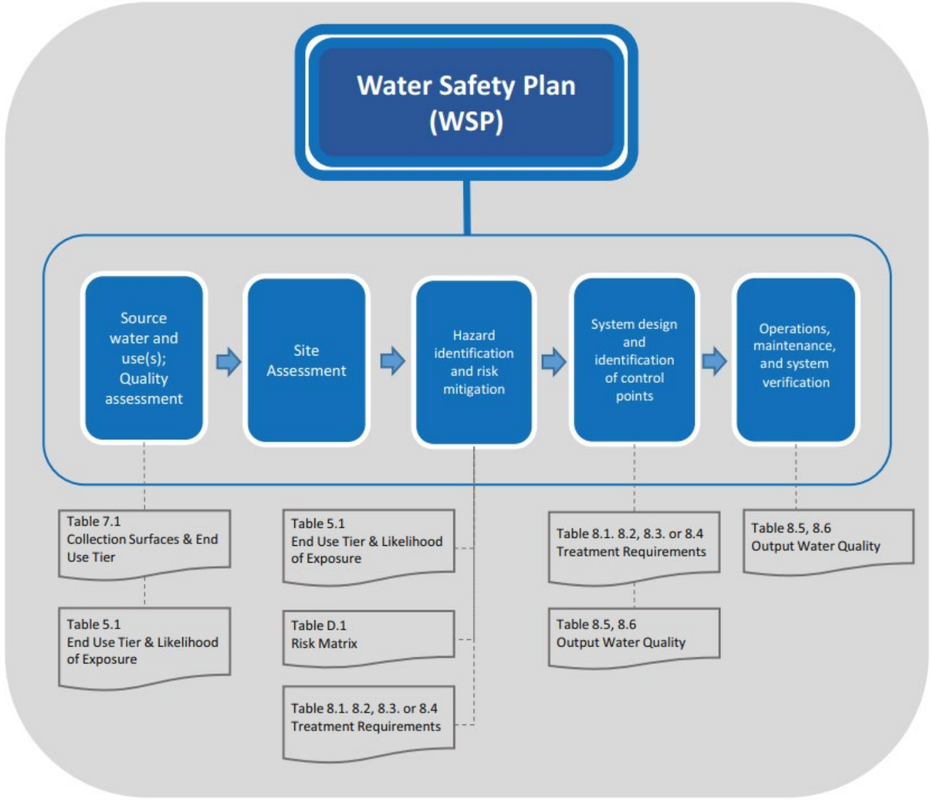
- The use of a first flush device to prevent the initial millimeters of harvested rainwater
- Cross-connection testing
- Regular inspections of inlets and vents
- Providing cleanouts in the water conveyance system

CSA B805-18 suggests the development of a water safety plan (WSP)

Instructions on filter cleaning and replacement, tank cleaning, gutter inspection, debris removal, and roof catchment inspection are missing



- The performance criteria should be applied in conjunction with a site -specific WSP rather than in isolation.
- The WSP is designed to address water quality concerns associated with RWHSs on a local, regional, and site -specific level.



Source: Standards Council of Canada (2018)

FUTURE PERSPECTIVES

A regulatory framework in Canada for wider implementation of RWHSs as a climate change adaptation measure:

- Industrial, agricultural, commercial, or surface water harvesting needs
- Maintenance and sampling frequencies
- Microbial and chemical targets
- Expanded uses

Anticipated investigations and studies:

- Existing RWHSs and their characteristics (i.e., design, operation and maintenance)
- Quality of water produced by residential, commercial and institutional systems
- Parameters and methods required to monitor and ensure the quality of the water produced

THANK YOU

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QUESTIONS?