The Village of LIONS BAY

# INFRASTRUCTURE COMMITTEE MEETING

**OF THE VILLAGE OF LIONS BAY**
**HELD ON TUESDAY, NOVEMBER 7, 2024 AT 6:00 PM**
**COUNCIL CHAMBERS, 400 CENTRE ROAD, LIONS BAY**
**AND VIA ZOOM VIDEO CONFERENCE**

TO JOIN THE MEETING, CLICK HERE:
https://us02web.zoom.us/j/2780145720?omn=87492415201
TO JOIN VIA PHONE, DIAL 778-907-2071 AND ENTER MEETING ID: 278 014 5720

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## AGENDA

1. **Call to Order**

2. **Appointment of Recorder**

3. **Approval of the Agenda**
   THAT the agenda be approved as submitted

4. **Public Questions & Comments**

5. **Approval of Minutes**
   A. **Infrastructure Committee Meeting Minutes (and notes) – August 08, 2024** *(page 4)*
   THAT the Infrastructure Committee Meeting Minutes of August 08, 2024 be approved as circulated.

6. **Business Arising from the Minutes** - *none*

7. **Unfinished Business**

| Identifier | Description | Responsible | Status |
|---|---|---|---|
| 23111 | All I.C. members will be provided with a copy of the IMP and the enhanced Asset Management Plan. The document is complicated and requires a dedicated I.C. meeting to fully understand the implications for the Village. | KB/PWM | |
| 23112 | Convene a February I.C. Round Table Meeting to focus on a 10 and 20 year horizon plan to identify the new and replacement infrastructure requirements and related expenses. | NTA/All | |

| | | | |
|---|---|---|---|
| 23113 | CAO and/or Council to be asked to allow members of the I.C. to have selective access to the PW document library. | PWM | |
| 23117 | BU will review the SCADA system on behalf of the I.C. and work with the PWM to up-grade the hardware and software. A Requirements Document is anticipated at mid 2024. | BU/PWM | Partial |
| 23121 | HM to assist the PWM in preparing REQ/RFP documentation for estimate and work on water main replacement Creekview Place and for the estimate for Highview Place. HM to assist the PWM and CAO in reviewing submissions once received. | HM/PWM | |
| 24044 | NTA to contact Staff to gain access to the 2015 water supply and tank fill time data and analysis and allow for joint review of improved real time data in 2024. | NTA | |
| 24052 | The potential for raw water shortages in 2024, and the possibility for compromised raw water quality after a forest fire necessities the Village has a full contingency plan for an alternative raw water supply. HM is to prepare a spreadsheet outlining the pros and cons of all the options to allow the I.C. to engage in a full discussion and recommendation to Council at a later date. | HM | |
| 24072 | BU requested that all water quantity and quality reports (Wells, water analyses etc.) be forwarded to him so a library, with everything in one place, can be maintained. | All | |
| 24073 | In light of discussion at the 03 July Finance and Audit Committee Meeting, the documents relating to asset management and asset replacement funding deficiencies need to be up-dated and presented to the F & A C, the CAO and staff and the Village as a whole. This should be an early Fall project for this group. | All | |
| 24081 | BU to set up and manage a Google Drive (or similar) to manage the water quality data as it is collected. | BU | |

## 8. New Business

A. **Next Steps** - **Long-term Raw Water Source (investigation and recommendation)** *(page 13)*

B. **Director of Operations Updates**

1. Show and tell on ASAP and peripheral improvements resulting (4 leaking UV reactor isolation valves, failed 8" strainer at PRV 1, partly non-functional fill station PRVs)
2. Show and tell on Oct. 18-20 atmospheric river
3. Finalising ENSURE NTU parameters: absolute and rate of change of values, as a function of anticipated streamflow
4. Brief on Carollo technical memo requests: tank fill setpoints, chlorine dosing
5. Brief on WHIRL@ Magnesia (Weir Height/Inclination ReaLign)
6. Brief on need and plans for front country toilet facilities at Sunset Trailhead
7. Brief on bringing road markings and signage to MUTCD and BC MSTSPM (with ICBC funding!), plus pay parking upgrades
8. Brief on plans for Translink-funded and MOTI-required bus shelter and trail access on Highway 99 SB onramp
9. Brief on SCADA improvements: alarming platform, switch to fibreoptic data lines, demonstration inline chlorine measurement at KG STP control room, MAGIC (Magnesia Intake Cutout) project, motor health readouts at STP and ASAP pumphouse
10. GIS/LIDAR needs
11. Brief on bridge-ends remediation project
12. PW/Infrastructure budget asks.

C. **UV Dose - Harvey Creek Water System – Regulators Questions**
   **i)** Compare UV reactors' specifications against regulator's requirements, to produce Construction Permit filing *(page 28)*

D. **Status Update on Last Budget Cycle** - IC recommendations and discussion on what to recommend for this year's budget

E. **Tony Greville - Requests for further discussion**
   **i)** How to we continue and improve upon lowering demand?
   **ii)** Making better use of the Alberta Creek supply.
   **iii)** Understanding the water quality from Alberta Creek

F. **UBCM Updates – Councillor Abbott**
   **i)** Portable Potable Water Treatment Skid *(page 65)*

**9. Public Questions & Comments**

**10. Adjournment**

**11. Next Meeting – November 21, 2024**

The Village of LIONS BAY

# INFRASTRUCTURE COMMITTEE MEETING
**OF THE VILLAGE OF LIONS BAY**
**HELD ON THURSDAY, August 08, 2024 AT 6:00 PM**
**COUNCIL CHAMBERS, 400 CENTRE ROAD, LIONS BAY**
**AND VIA ZOOM VIDEO CONFERENCE**

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## MINUTES

| | |
|---|---|
| In Attendance : | Councillor Neville Abbott – Chair<br>Committee Member Anthony Greville<br>Committee Member Hilary Monfared – Via Zoom<br>Committee Member Brian Ulrich |
| Absent with regrets : | Mayor Ken Berry<br>Councillor Jaime Cunliffe |
| Staff : | Director of Operations Karl Buhr |

**1. Call to Order**

The Chair called the Infrastructure Committee Meeting order at 18:06 pm.

**2. Appointment of Recorder**

ASG was appointed recorder this meeting.

**3. Approval of the Agenda**

*Moved/Seconded*
THAT the agenda of August 08, 2024, Infrastructure Committee be adopted as circulated.
**CARRIED.**

**4. Public Questions & Comments**

No public comments or delegation were forthcoming.

**5. Approval of Minutes**

A. Infrastructure Committee Meeting Minutes – July 02, 2024.
THAT the Infrastructure Committee Meeting Minutes of July 02, 2024 be approved as circulated.
**CARRIED.**

**6. Business Arising from the Minutes**

**7. Unfinished Business**

**24021 –** This item is now considered to be complete.

**24022 –** With the Alberta Creek project (ASAP) to be commissioned during the week of 12 August, 2024, the I.C. involvement is now complete.

**24051 –** A UBCM Meeting Request discussion note to Council has been submitted, and so this item is now complete.

**24071 –** ASG and the DOO met and prepared an ENSuRe trigger point protocol, which has been submitted to the I.C. and has been approved. As an addition, the tripper point notes include a recommendation to increase the water quality analyses of Alberta Creek (under ASAP), with a view to potentially allowing Alberta Creek water to be a substitute source if an when Harvey Creek supply is shut off due to ENSuRe. Future work and evaluations will be required. For now, this item is complete.

**24072 –** Information and data is slow coming in to BU. To facilitate and manage the data, BU is to set up a Google Drive, or similar.

**8. New Business**

A. Active Transportation Grant.
Determined the Active Transportation Grant is not really an I.C. responsibility and should be either a staff function or handed through a different committee ~~to the Funding and Grant Preparation Committee~~. See discussion point~~s below~~ for further information.

B. The UBCM Summary Report.
The UBCM delegation request summary has been submitted, and accepted with a few minor grammatical adjustments.

C. The ENSuRe Trigger Points recommendation.
The recommendation has been accepted by the DOO and it is the intention to move ahead and submit the protocol to VCH. See discussion point below for further information.

D. Director of Operations Up-date.
The Director of Operations reports that currently approximately 50% of all the flow into the Kelvin Grove WWTP can be considered to be I & I, and this represents almost 10% of the total water demand. The PWD is increasingly looking at leakage from household toilets to lower overall water demand withing the Village.

As of 08 August, overall water demand remains at 50% of 2023 demand, and water supply is able to meet this lower demand.

The ASAP project remains on time (commissioning still expected to occur on or about 15 August) and the finalized costs are under budget. See discussion points ~~below~~ for further information on all DOO topics.

**9. Public Questions & Comments**

No public comments or delegation were forthcoming.

**10. Adjournment**

*Moved/Seconded*

THAT the Infrastructure Committee Meeting be adjourned.

**CARRIED**

The meeting adjourned at 20:03.

**11. Next Meeting**

Next meeting of the Infrastructure Committee was scheduled for September 12, 2024.

# INFRASTRUCTURE COMMITTEE MEETING
## OF THE VILLAGE OF LIONS BAY
## HELD ON TUESDAY, August 08, 2024 AT 6:00 PM
## COUNCIL CHAMBERS, 400 CENTRE ROAD, LIONS BAY
## AND VIA ZOOM VIDEO CONFERENCE

## Discussion and Background Notes

Contributions by: Anthony Greville

Also in attendance: Ken Berry
Neville Abbott
Hilary Monfared
Karl Buhr (PWM)
Brian Ulrich

**Discussion and Background Notes.**

| Identifier | Description | Responsible | Status |
|---|---|---|---|
| 23111 | All I.C. members will be provided with a copy of the IMP and the enhanced Asset Management Plan. The document is complicated and requires a dedicated I.C. meeting to fully understand the implications for the Village. | KB/PWM | |
| 23112 | Convene a February I.C. Round Table Meeting to focus on a 10 and 20 year horizon plan to identify the new and replacement infrastructure requirements and related expenses. | NTA/All | |
| 23113 | CAO and/or Council to be asked to allow members of the I.C. to have selective access to the PW document library. | PWM | |
| 23117 | BU will review the SCADA system on behalf of the I.C. and work with the PWM to up-grade the hardware and software. A Requirements Document is anticipated at mid 2024. | BU/PWM | Partial |
| 23121 | HM to assist the PWM in preparing REQ/RFP documentation for estimate and work on water main replacement Creekview Place and for the estimate for Highview Place. HM to assist the PWM and CAO in reviewing submissions once received. | HM/PWM | |

| | | | |
|---|---|---|---|
| 24021 | Continue to work with the CAC to prepare a joint recommendation to Council with respect to both short term zone water metering and longer term universal metering. | All | ✓ |
| 24022 | Assist the PWM/PWD in any way by providing time and expertise in regards to enabling flow from Alberta Creek to be diverted into the Harvey Creek WTP to supplement our potable treated water supplies during the summer of 2024 and beyond. | All | ✓ |
| 24044 | NTA to contact Staff to gain access to the 2015 water supply and tank fill time data and analysis and allow for joint review of improved real time data in 2024. | NTA | |
| 24051 | Review the potential consequences of a major forest fire above the Village on our watersheds and report back to Council with a firm recommendation as to the best course of action to ensure a continuous potable water supply. | All | ✓ |
| 24052 | The potential for raw water shortages in 2024, and the possibility for compromised raw water quality after a forest fire necessities the Village has a full contingency plan for an alternative raw water supply. HM is to prepare a spreadsheet outlining the pros and cons of all the options to allow the I.C. to engage in a full discussion and recommendation to Council at a later date. | HM | |
| 24071 | ASG and DOO are to work together to generate the ENSuRe water quality “trigger points and conditions.” | ASG/DOO | ✓ |
| 24072 | BU requested that all water quantity and quality reports (Wells, water analyses etc.) be forwarded to him so a library, with everything in one place, can be maintained. | All | |
| 24073 | In light of discussion at the 03 July Finance and Audit Committee Meeting, the documents relating to asset management and asset replacement funding deficiencies need to be up-dated and presented to the F & A C, the CAO and staff and the Village as a whole. This should be an early Fall project for this group. | All | |
| 24081 | BU to set up and manage a Google Drive (or similar) to manage the water quality data as it is collected. | BU | |

**NOTES:**

XXXXX

**Active Transportation Grant.**
After some discussion it was felt that active participation in determining the parameters and then writing a submission to the Active Transportation Grant was probably not within the remit of the I.C. The question of applying for some grant monies to build washrooms at the hiking trails entrances was reviewed, and while there was some doubt as to whether this idea might qualify, there was also the position that we should apply because we just might be successful.
HM reported she has considerable experience in writing community Active Transport Plans in her professional life. HM further commented that Lions Bay has holes in our transportation plan, and would benefit from preparing an official Active Transportation Plan.
The top priority recommendation from the I.C. to Council for 2024 was to initiate repair of community bridges, parking is the major issue within the Village (after trees!), we have had recent debate concerning "quiet pavement" and Stop signs at various railway crossing etc. Our transit service is threatened due to low ridership and budgetary concerns. And the CAC is always looking at ways to reduce GHG emissions by improving mass transit and electrification of the automobile. An overall Active Transport Plan should be in place, an in terms of grant funding to satisfy the myriad of transportation project needed to sustain the Village.
While the I.C. may step aside in terms of responding to a current grant opportunity, the suggestion the I.C. assist in the development of a Active Transportation Plan carried merit.

**The UBCM Summary Report.**
The UBCM Summary Report was reviewed, and after a few minor changes were suggested, mainly grammatical in nature, which were accepted, the report was approved. The report will be delivered to Council by the I.C. Chair for the Conference in early September.

**The ENSuRe Trigger Points Recommendation.**
The DOO had requested a recommendation from the I.C. with reference to potential Trigger Points for the ENSuRe protocol. ASG met with DOO and PW staff and subsequently prepared a report outlining the recommendations. In general, these recommendations have been accepted by staff, although the DOO reports the operating staff would like to make some local modifications.
The PWD will move ahead with the recommendations, and will prepare a budget for the proposed particle counters etc.
The report did expand upon its original intent when the question arose as to replacement water in the event ENSuRe does indeed shut down the Harvey Creek intake. The pending commissioning of the Alberta Creek source into the Harvey Creek plant during summer drought presents an interesting option to use this same source during winter time turbidity spikes. There is currently (limited) evidence to suggest the water from Alberta Creek is different that that from Harvey Creek (pH, alkalinity, hardness etc.,) suggesting it might be partially, or predominantly spring fed rather the surface snow melt fed.

If this is the case, it might (stress might) happen that Alberta Creek would not be susceptible to significant turbidity incursions after heavy winter rainfall. If this is the case, then during times of excess turbidity in Harvey Creek, Alberta Creek could be fed into the Harvey system resulting is less water stress to the Village during the winter rainy season.
To this end, it was proposed that during the up-coming fall, winter and spring seasons, Alberta Creek be analyzed frequently, and especially immediately after a heavy rainfall, when the Havery and Magnesia Creeks shown excess turbidity, to determine the true quality of Alberta Creek.

Should these quality analyses prove to be positive, then the current ASAP project could be expanded to being a full year option rather than a 6 – 8 week option, improving the value to the Village and allowing for more confidence in our local water supply. This might involve twinning the line and purchasing two more pumps, as a mid term project.
This suggestion took on a little more urgency after the DOO reported that Drinking Water Officer from VCH is requesting the ENSuRe protocol provide for automatic closing of the Harvey Creek intake valve, and that raw water UVT be a part of the protocol (it was included in the I.C. recommendation).

**Director of Operations Up-date.**
The DOO reported that currently, during the middle of the night, there is considerable flow into the Kelvin Grove WWTP. During the busy day, this flow doubles, suggesting approximately 50% of all the flow into the Kelvin Grove WWTP can be considered to be I & I. The numbers are showing 1.45 litres/second were flowing into the K.G. WWTP at night.
Extrapolating this out, 1.45 l/s is 87 l/min or 125,280 l/day, or 33,100 usgpd. This is equal to 10% of the entire Village's non-irrigation demand. Even more enlightening; if each Village resident consumed 400 lpppd, then total Village demand would be 560,000 l/day, or 150,000 usgpd. In this scenario, a few leaking toilets in Kelvin Grove represents 22% of the total Village potable water demand!
The DOO suggested the DWD has determined this flow into the K.G. WWTP is from 4 or 5 toilets in the subdivision.
Not too surprisingly, if leakage is a major issue contributing to the excessive water demand in Lions Bay, in addition to finding water leaks in the ground, the next phase of water conservation should be to initiate a "knowledge blitz" on leaking toilets and taps inside the local residences.
Some communities go one step further and supply and install new cisterns in old and leaking residential toilets and fix dripping taps for free. This might be something Lions Bay could consider so save monies in 2025?

As of 08 August, overall water demand remains at 50% of 2023 demand, and the current water supply is able to meet this lower demand. On the day, demand was 420,000 usg, well below the 800,000+ usgpd day in mid August 2023. There was a rain event a few days prior, and demand dropped to 325,000 usg for two days after. Consumer awareness, and energy spent fixing the major leaks in the Village, is paying considerable dividends as we enter the critical 6 – 8 week low raw water supply window.
While demand fluctuated a little below 45,000 usgpd, supply volumes are dropping as surface supplies are depleted. We are not yet into the groundwater source supply scenario; the sources changed on approximately 17 August in 2023.

Current supply is approximately 1,000,000 usgpd, or a little over twice the demand. However, this supply is now less than the total nominal WTPs capacity of 1,400,000 usgpd. The supply volume has been calculated based in current flow in Harvey Creek and has only considered the use of the 2" line into the Magnesia Creek WTP. Supply can be increased into Magnesia Creek WTP if the 4" line is utilized. This will lower the retention time and so impact Ct, however, the revised baffle factor calculation for Magnesia Creek will allow for this extra water draw should it be necessary. Currently, all chlorine residual parameters are being met, and should the flow double through the Magnesia Creek plant, extra attention will be paid to these measurements.

Any gains realized due to the addition of Alberta Creek as a raw water source have not be factored into this supply calculation.
During the week of 02 August, demand from the Bayview PRV had increased substantially; it is known there are two "difficult to fix" leaks on Bayview Road below the PRV, and it is thought one has significantly increased in flow in recent days. This leak will be attended to as soon as a hydro-vac truck can be booked.
With demand remaining constant as less than 500,000 usgpd, but with supply decreasing, it is thought Level 2 water restrictions may be necessary in 15 – 20 days' time. If demand remains constant, and Alberta Creek is successfully brought on line, and Magnesia Creek WTP flow can be doubled, it is hoped Level 3 water restrictions can be avoided for 2024.

The ASAP project remains on time, commissioning still expected to occur on or about 15 August, and the finalized costs are under budget. The DOO presented some photographs and short videos of the project to date, including the new intake at Alberta Creek and some bucket testing to determine flow. Bucket testing a day or so earlier indicated a flow of 190 usgpm was in the Alberta Creek.
A turbidity meter and particle counter will be added to the supply line at the Oceanview Tank pumphouse as a part of the project to ensure water quality at all times.
Flow calculations suggest the maximum flow through the pipe to the Oceanview tank will be 119 usgpm, while the maximum flow through the two stage centrifugal pump will be 50 usgpm. 50 usgpm is equal to 72,000 usdgpd, or approximately 17% of the total irrigation season flow. In the event Harvey Creek supply cannot meet demand, irrigation will be banned, and demand will be encouraged to be less than 300,000 usgpd. At this time, even 50 usgpm will represent 25% of total Village demand.
As a proposed supplemental source, to be employed during times of low flow in Harvey Creek, the project has been a success. The value of this project to the Village could be enhanced by a twinning of the line, and adding additional pumps will allow for Alberta Creek to replace the Harvey Creek source in the winter when Harvey Creek is taken off line due to elevated turbidity loadings.
Work needs to be done in regards to this second benefit, but for now, once commissioning is complete, the Village will be considerably more secured as far a summer time water flow is concerned.
The proposed budget was $721,000; it was reported the engineering costs for the project were $125,000, while hard civil costs were $425,000, for a total of $550,000. If a few extra and taxes are included, the final cost will likely be a little over $600,000, so well under budget.

**Long term water supply options for Lions Bay.**
Brian, can you fill in here?

My notes shown the following;

I know we have settled in a base line demand of 500,000 usgpd (which is still far too high at 1,350 lpppd opposite a Canada wide 320 lpppd and even 420 lpppd in West Vancouver).

I have notes we talked about the possibility of utilizing wells drilled into the land immediately adjacent to Harvey and Magnesia Creeks, so within the boundaries of the Village, to draw from the water in those creeks that is found below the surface. It was felt this could work to stabilize supply, keep the water supply free from outside political interference, and we know the groundwater close to the creeks is of good quality (since we draw from it when the creek surface supply dries up.

I believe you were going to expand the Table of Criteria in your spreadsheet for the next meeting.

I also have in my notes that we would then consider assigning some responsibilities to the tasks shown in the Table of Criteria, and we would be very open to having each I.C. member lead a group of the **qualified** Village citizens as the number of tasks would be impossible for a group of 4 or 5 individuals to address in any sort of short term timetable.

# Lions Bay long term Water supply strategy

## Problem Statement:

*Under certain conditions, Lions Bay could face future potential for water shortage and/or poor, unacceptable water quality.*

**Potential Water Shortage – mostly a seasonal risk**

Lions Bay currently draws its water supply from surface water via two Howe Sound mountain creeks; Harvey and Magnesia Creeks. During 9-10 months of the year the water supply from the creeks is well in excess of the village's consumption demands. However, in some years, when snowpack is low, the hot summer months see the creeks' flows very low or non-existent, risking supply not being able to meet demand. This is the seasonal nature of the risk. Uncommon events like earthquakes or other disasters could also induce water shortages.
The minimum continuous water flow requirement is: 500,000 USgal/day, without ever having to revert to the restrictions of water conservation level 3.

**Potential Water Quality – mostly a risk from uncommon events**

Although the Village deals with periodic water quality issues due to its lack of filtering as part of the treatment system, these incidents are short lived. With this system, however, a forest fire in the Village's watershed could present more serious long term water quality issue. The current system cannot remove or treat the contaminants that would leach out of the burned forest bed into the creeks, and ultimately our water distribution system for up to 5 years after a fire.
The minimum continuous water quality requirements are: XXX

## Objective:

*Identify and implement Improvements to the Village's water system so that the needed water quantity and quality can be provided to residents continuously 24/7/365, even during and/or after the risk situations mentioned in the problem statement.*

'Improvements' does not exclude completely replacing the existing system with something totally new. However, despite its shortcomings, the Village's water supply system (intake, treatment, distribution) has had a lot invested in it and is worth trying to build upon and improve, as opposed to abandoning in lieu of something new. Ideally, any improvement(s) would address both potential shortage and potential quality issues at the same time, but separate solutions to the separate issues may prove to be more practical.

## **Addressing water shortage (supply) issues**

*For 9 or 10 months of every year we have much more water than we need or can use.*
(aka a reliability issue)

The recurring (seasonal) risk of water shortage during the summer months requires peak shaving; a short term solution to provide water over and above that of the existing supply system, to meet temporarily high demand.
The only two solutions to peak demand are to reduce demand or obtain more water from another source, separately or in combination.
Reducing demand relies on residents' cooperation and although historically effective, may not be enough in the future.

Consequently this assessment focuses on how to obtain water from other sources, primarily for peak shaving, but also with the possibility to be a full-time long term water source. (The feasibility and cost of a full-time replacement water source to solve a periodic, peak shaving issue, will obviously be difficult to justify).

Monitoring of demand over the last couple of years shows that the village's per capita consumption has been as high as 3 times the 300,000 usg/day average of other urban areas, Vancouver specifically. This is mostly due to leakage, which is being addressed aggressively. Reducing the Village's water consumption to meet that average will be a challenge in the medium term due to the age of the current water infrastructure. Therefore the initial target demand has been set at 500,000 usg/day for this assessment.

**Potential new water sources:**
These are the to-date identified sources of additional water that could be tapped to augment the Village's current creek supply (with no ranking as to cost or feasibility):

- Mountain lake or reservoir
- Wells
- Pipeline from other jurisdiction (Metro/North Vancouver or Squamish)
- Desalination plant
- Draw from more surrounding creeks
- Rain Collection

- Natural springs
- Floating water supply barge
- Man-made additional storage pond in gravel pit
- Do nothing
- Other?

These options have in the past been assessed in various levels of detail and need to be more thoroughly evaluated and ranked against several criteria to identify the top candidate(s). The following table shows the current subjective or qualitative status and understanding of these options.

Ranking is from 1 to 10 where 10 is best (easiest/fastest/strongest/cheapest etc). Option with highest total ranking of all criteria is the preferred option.

| Ranking of Potential Additional Water Sources | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | Current understanding of the source cost/feasibility (10 = good) | Additional water volume possible (10 = lots) | Ease of technical solution (10 = easy) | Ease of political adoption (10 = easy) | Low Cost (10 = lowest) | Fast to implement (10 = fast) | Ability to accommodate population growth | Easy to connect to existing water system (10 = easy) | Resilience to Climate & Enviro shocks & stress (10 = most resilient) | Source has minimum land impacts (10 = no impact) |
| Mountain Reservoir - 46 | 2 | 8 | 10 | 5 | 1 | 1 | 8 | 2 | 7 | 2 |
| Wells - 62 | 5 | 5 | 4 | 7 | 6 | 6 | 6 | 7 | 8 | 8 |
| Pipeline from West Van - 57 | 4 | 10 | 6 | 4 | 4 | 4 | 8 | 2 | 9 | 6 |
| Desalination Plant - 68 | 3 | 10 | 5 | 7 | 5 | 6 | 10 | 5 | 10 | 7 |
| Surrounding Creeks - 39 | 1 | 2 | 5 | 7 | 3 | 3 | 5 | 3 | 5 | 5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rain Collection -52 | 2 | 2 | 3 | 9 | 6 | 7 | 2 | 7 | 6 | 8 |
| Natural Springs -0 | 0 | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| Floating Barge - 48 | 1 | 2 | 5 | 7 | 4 | 7 | 6 | 4 | 9 | 3 |
| Storage Pond -48 | 1 | 3 | 3 | 6 | 5 | 6 | 5 | 6 | 8 | 5 |
| Do nothing -73 | 10 | 0 | 10 | 3 | 10 | 10 | 0 | 10 | 10 | 10 |
| Combinations of the above | - | - | - | | - | - | | | | |

The current level of understanding of each additional water source dictates the accuracy or validity of ranking for each of the associated topics (volume, difficulty, cost, time). More details of the current understanding of each source are provided below.

**Mountain Reservoirs – Natural and man-made**

Mountain lakes/reservoirs capture rain and snowmelt, providing reliable water supply, depending on the size, and eliminate the intermittency characteristic of creek flow sources. The Capilano reservoir supplies the City of Vancouver in such a manner. The potential for such a supply for Lions Bay is more limited. Natural reservoirs like Enchantment Lake and possibly Deeks Lake are two mountain lakes above Lions Bay that are possible candidates, Enchantment, more so because of its proximity.

Tapping into Enchantment Lake would require either pumping water up over the Howe Sound Ridge and into the Harvey catchment or drilling directly through the mountain to allow gravity feed the entire distance to Lions Bay. The lake and almost entire distance to Lions Bay is on crown land which would trigger numerous political and environmental hurdles.

The Capilano reservoir is a man-made lake held back by a large dam constructed many years ago. Creating such a structure on crown land to back up Harvey or Magnesia creeks today would face even more hurdles than tapping into Enchantment Lake, so it ranks high (i.e. poorly) on all categories and is not realistically included any further in these discussions.

This option involves elements outside the Lions Bay Municipal boundaries therefore various political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:
Previous Feasibility Studies or Evaluations available: None
Consensus from evaluations to date – Water Volume: None
Consensus from evaluations to date – Feasibility: None
Consensus from Cost Estimates available to date: None

**Wells**
Well water as an additional source started getting significant attention in 2015 which was a dry summer with supply concerns. Subsurface water in the Harvey and Magnesia creek beds kept filling our tanks that summer albeit slowly, so the value of wells was considered. A brief survey showed that several communities along Howe Sound get portions or all of their water from wells. Some, but not all communities treat their well water for arsenic. None of the Lions Bay creek sources contain any significant arsenic, which is encouraging, but deeper subsurface water quality will remain unknown until a test well is drilled.
Further investigations into the feasibility and cost of wells in the Village have been conducted this year which give best understanding to date of the drilling costs. Further cost, treatment and access elements need to be added to these latest assessments to get a complete understanding of the option.

All parts of this option would be contained within the Lions Bay Municipal boundaries so hurdles from outside jurisdictions, aside from Vancouver Coastal Health, are minimal.

State of our assessment:
Previous Feasibility Studies or Evaluations available:
- -Piteau Associates Hydrological Assessment, 19 March 2005
- -B. Ulrich Survey Feb 2017
- -M. Sredzki Delegation to Council 19 March 2024
- -Ken Berry email report on meeting with Hydrologist, Ridgline & Piteau, 3 May 2024
- -Other?

Consensus from evaluations to date – Water Volume: None
Consensus from evaluations to date – Feasibility: None
Consensus from Cost Estimates available to date: Partial: drilling only – $30-$35K per 200 ft

**Pipeline from Metro/North Vancouver**

This option makes Lions Bay reliant on water supply from another jurisdiction with much larger capacity, either Squamish or West Vancouver, the latter being the more capable and practical. It's not know if Squamish has either the capacity or desire to supply another jurisdiction. Triggered by the 2015 dry spell, discussions were held with West Vancouver to explore the possibility of a pipeline to Lions Bay from the Capilano supply system. West Vancouver did not outright reject the proposal and a subsequent preliminary cost estimate was floated with the IC at the time. This would entail a surface or buried pipeline from Horseshoe Bay to Lions Bay along the Sea to Sky highway. Rough cost estimates of $XXX per km prompted the option to be set aside as too expensive at the time.

This option involves elements outside the Lions Bay Municipal boundaries therefore various political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:

Previous Feasibility Studies or Evaluations available:

- -Discussions, ? from LB and ? from West Van, ? 2016?
- -Other ?
- -Other ?
- -Other ?

| | |
|---|---|
| Consensus from evaluations to date – Water Volume: | None, but assumed to be sufficient |
| Consensus from evaluations to date – Feasibility: | None |
| Consensus from Cost Estimates available to date: | Partial: $xxx per km |

**Desalination Plant**

Lions Bay is situated immediately next to an endless supply of water if it can be made potable; i.e. desalinated. A desalination plant could be sized only for peak shaving, or for a larger permanent supply of the entire Village all year round. The former would feed into the existing treatment system. The latter would essentially replace the existing creek supply system including decommissioning the UV reactors. However post treatment to maintain residual chlorine levels in the distribution system is still required. In addition to the plant itself, both scenarios require a large pump system to lift the water to either the Harvey or Magnesia tanks or both, in order to enter the distribution network. Either way, desalination is an expensive option, obviously more so if it becomes a permanent solution.

All parts of this option would be contained within the Lions Bay Municipal boundaries so hurdles from outside jurisdictions, aside from Vancouver Coastal Health, are minimal.

State of our assessment:

Previous Feasibility Studies or Evaluations available:

-Discussions, ? from LB and ? from ?supplier, ? 2016?

-Other ?

-Other ?

-Other ?

Consensus from evaluations to date – Water Volume: None, but assumed to be sufficient

Consensus from evaluations to date – Feasibility: None, but

Consensus from Cost Estimates available to date: Rough estimate: $xxx

**Surrounding Creeks**

Lions Bay has water licenses for all 3 creeks running through its municipal boundaries, and re-activation of draw from Alberta creek is being implemented as this summary is being written. When the project is complete it will be better understood how much additional water it will supply to the system during peak periods. Alberta Creek seems to still flow in late summer when Harvey and Magnesia dry to a trickle.

There are other creeks in the vicinity of the Village, most notably Rundle & Lonetree Creeks to the south and M creek to the north. These could potentially provide additional water to augment in peak periods although, being creeks, they too will have reduced flow in dry periods. Consequently this option has not been discussed at any length but deserves a slot in this analysis.

Drawing water from these additional creeks would require obtaining a water license for each and constructing intakes on each with pipeline feeds into our current treatment systems. The water quality of these creeks is currently unknown, and absent any assessment it is not known if the amount of additional water available would be worth the investment.

This option involves elements outside the Lions Bay Municipal boundaries therefore various political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:

Previous Feasibility Studies or Evaluations available: None

Consensus from evaluations to date – Water Volume: None

Consensus from evaluations to date – Feasibility: None

Consensus from Cost Estimates available to date: None

**Rain Collection**

The Island of Bermuda has no fresh groundwater and relies almost 100% on collection of rainwater for its water supply. (only recently have some tourist hotels been able to afford desalination to support the high demand of the arriving cruise ship passengers). That rainwater capturing infrastructure was built over many years so any such infrastructure of comparable capacity for Lions Bay would not be a near term solution. However, initiating it now as a long term strategy would be both effective and cost effective.
Every residence in Bermuda must have minimum 13,000 liter cistern capacity under the building for each bedroom in the residence, for collection of rain. Consequently every inch of rooftop space is designed for effective rain collection. This would need to be incorporated into Lions Bay building bylaws for all new buildings and allowed to take effect over time, with very minimal cost to the village.

In the short term, however, rain collection would be limited to programs that encourage residents to collect rain in barrels and tanks for use in applications like gardens, washing cars and applications that do not require treated potable water from our system. Ad hock initiatives like this were undertaken in the dry summer of 2015 with residents buying collection barrels etc, but there is currently no ongoing village-endorsed program to encourage this.

All parts of this option would be contained within the Lions Bay Municipal boundaries so hurdles from outside jurisdictions, aside from Vancouver Coastal Health, are minimal.

State of our assessment:

| | |
|---|---|
| Previous Feasibility Studies or Evaluations available: | None |
| Consensus from evaluations to date – Water Volume: | None but anticipated to be low |
| Consensus from evaluations to date – Feasibility: | None |
| Consensus from Cost Estimates available to date: | None |

**Natural Springs**

It is not known if there are any underground springs in proximity of the Village that could supply water if tapped. The fact that Alberta Creek continues to flow in dry summers when Harvey and Magnesia are reduced to a trickle implies that there might be a significant underground source of water in addition to the background subsurface moisture that feeds the creeks when snowpack or rain is absent. Although the Village will soon be taking advantage of the flow in Alberta Creek the initiative will provide only limited information as to the existence of a natural spring in the catchment. There does not seem to be any identified water flows in the area during dry times that might indicate the presence of springs outside the Alberta Creek catchment. Consequently, there has been no significant or meaningful discussion about natural springs as an additional water source.

The ongoing UBC hydrology study that Lions Bay has commissioned is intended to help understand the nature of subsurface water in our watersheds and ultimately how much it can be relied on as part of our water source. Any such results would hopefully identify the existence of natural springs in the area. The study, however, has been hampered somewhat by technical issues (communications with test sites etc) so meaningful results and conclusions are not expected in the near term.

This option involves elements unknown but potentially outside the Lions Bay Municipal boundaries therefore various political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:

| | |
|---|---|
| Previous Feasibility Studies or Evaluations available: | None |
| Consensus from evaluations to date – Water Volume: | None |
| Consensus from evaluations to date – Feasibility: | None |
| Consensus from Cost Estimates available to date: | None |

**Floating Barge**

A floating barge would be moored somewhere close to the Lions Bay shore and store a finite quantity of water. It would have to be connected to the current water system, in a fashion dictated by the quality of the water stored. Connection to the existing water system would likely require a pumped line up to the current reactor for treatment plant so it can then flow into the existing water distribution. If the stored water is potable and can be maintained that way on the barge, the water could be injected into the lower part(s) of the existing water distribution but would require very large pumps to overcome the gravity pressure in our existing lines. The latter option would essentially be pushing water backwards through our current system of PRV's and valves which might eliminate it as a connection option for this source.

The drawbacks with the barge solution are that it holds only a finite quantity of water, which needs to be refilled, and it's position will inevitably be considered an eyesore or obstruct several residents' views. These issues make the solution a political challenge to sell to the residents.

The volume of water the barge could store would be approximately equivalent to our Harvey tank, which only provides a day or two of water in peak times as a primary source. Calculations need to be done to estimate how long it would last as a peak shaving solution.

Refilling the barge would require disconnection of the feed to our existing infrastructure (without disrupting pressure or introducing contamination), and transporting the barge to a station capable of filling it. The costs of the water and repeated transport need to be compared with those of the stationary options.

This option involves elements outside the Lions Bay Municipal boundaries therefore various political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:

| | |
|---|---|
| Previous Feasibility Studies or Evaluations available: | None |
| Consensus from evaluations to date – Water Volume: | None |
| Consensus from evaluations to date – Feasibility: | None |
| Consensus from Cost Estimates available to date: | None |

**Storage Pond**

A storage pond big enough to hold a worthwhile volume of water could be dug/built up on the gravel pit site at the north end of the village. The water would have to be injected into the existing distribution system via the existing water treatment plant(s). The sight has some elevation so pumping water to the reactors will be a bit easier than pumping water from barge or desalination at sea level. It is also quite close to the Magnesia creek reactor, making such a feed relatively short.

Unless the village chose to have the pond filled/refilled by trucking in water, which seems impractical, filling and refilling of the pond would depend on rain and surrounding surface runoff. Both of those sources are, by definition, weak or nonexistent during dry peak periods. Essentially, it would be a central rain storage system. Therefore the pond would have to be as large as possible to effectively peak shave during dry spells. The local depth of bedrock under the site may also dictate that the pond be built above ground. It would not be an option as a primary source of water.

This option does not involve elements outside the Lions Bay Municipal boundaries therefore fewer political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:

| | |
|---|---|
| Previous Feasibility Studies or Evaluations available: | None |
| Consensus from evaluations to date – Water Volume: | None |
| Consensus from evaluations to date – Feasibility: | None |

Consensus from Cost Estimates available to date: None

**Do Nothing**

Simply doing nothing is indeed an option, and an easy one at that. However it does not address the stated problem, and therefore is not expected to be a candidate solution.

As of this current revision, the ranking of this option is higher than all other options. This would indicate that the criteria rankings of each source or the ranking system itself may be missing something. Discussion is required

This option involves no elements outside the Lions Bay Municipal boundaries therefore no political, regulatory, environmental and other hurdles from outside jurisdictions would be encountered.

State of our assessment:

Previous Feasibility Studies or Evaluations available: None
Consensus from evaluations to date – Water Volume: None
Consensus from evaluations to date – Feasibility: None
Consensus from Cost Estimates available to date: None

**Combinations of described sources**

It may turn out that none of the aforementioned additional water sources can alone provide the required improvements to the Village's existing water system. In combination, however, several of them may prove to be effective solution with palatable cost and timeframe. This is a concept that has not been discussed much but which presents numerous combinations of water sourcing that might easily relieve peak demand issues.

For example, wells may never supply sufficient water for the whole village but would be worth tapping for the immediate zone(s) around them. At the same time, a small desalination plant could supply properties within close proximity to the shoreline without the expense of pumping water all the way up the main tanks. These two, temporarily isolated from the main distribution system, would reduce demand on the main Harvey/Magnesia supply enough to make it through peak periods comfortably. Such a scenario necessarily involves monitoring, coordination, and controls, not to mention possible taxation and clerical issues.

This option involves elements mostly but not all inside the Lions Bay Municipal boundaries therefore a few political, regulatory, or environmental hurdles from outside jurisdictions may be encountered.

State of our assessment:
Previous Feasibility Studies or Evaluations available: None
Consensus from evaluations to date – Water Volume: None
Consensus from evaluations to date – Feasibility: None
Consensus from Cost Estimates available to date: None

## Addressing water quality issues

*There are basically three categories of contamination that can affect water quality, each caused by or coming from a different source or event. These are particulate contamination, biological contamination and dissolved organics contamination. The Lions Bay water treatment system consists of UV reactors followed by chlorine injection. This system effectively deals with only some of the above contaminants.*

**Particulate contamination**

*The current Lions Bay water treatment system does not effectively address particulate contamination.*

This type of contamination is normally present in moving surface water as in creeks and rivers, and to a lesser extent still surface water as in lakes and reservoirs. Particles of various sizes suspended in the water themselves usually do not represent a health hazard, but they make the water murky and give it an unattractive appearance. More importantly however, they can reduce or completely inhibit the effectiveness of systems that treat the water for biological or toxic elements. Mud washed down the creek and into the water system after a winter storm is an example of what Lions Bay experiences periodically. The current treatment system does not deal with turbidity and consequently if it is high enough, it shuts down the UV reactors.

Dealing with particulate contamination usually involves physical removal of the particles from the water by various forms of filtration.

**Biological contamination**
*The current Lions Bay water treatment system does effectively address biological contamination under certain conditions (i.e., low turbidity)*

This category includes microorganisms, viruses and other pathogens in the water which can cause illnesses in humans. It also is most commonly associated with surface water and is caused mostly by human and animal activity in the watershed. The list of these contaminants is well established and a common example of this would be e-coli contamination from human or animal feces. The Lions Bay UV reactors effectively de-active pathogens in the water but only when the water is clear (low turbidity and high transmissivity).

Dealing with biological contamination can be done by physical removal of the pathogens from the water by various filtration methods or by sterilizing/deactivating or killing the pathogens using UV, Ozone, chlorine or other methods so their continued presence in the water is harmless.

**Dissolved organics and metals (DOM)**
*The current Lions Bay water treatment system does not effectively address dissolved organics contamination.*

This type of contamination is most commonly recognized in ground water as in wells and springs but can also be found in surface water after significant events, notably forest fires. This type of contaminant is not a short-lived effect, often being an inherent characteristic of the ground water (arsenic content for example), or from an unusual even causing long term lingering effect like leaching of elements from a burned forest into the surface water.

Some non-biological elements, compounds or metals dissolved into water are beneficial or desirable, but others are toxic and harmful and need to be dealt with. Since Lions Bay draw its supply from surface water, dissolved organics has not been much of an issue for water quality and the water treatment system was therefore not designed to handle DOM. However, the risk of a forest fire in the watershed(s) above Lions Bay poses a risk of DOM's entering the water supply, and rendering it unpotable despite the current treatment system.

These types of contaminants cannot be removed by physical means alone but must be treated chemically, which can often generate solids which must be removed physically.

## Improving the Lions Bay system for water quality

Given that the current Village treatment system is only a partial solution against the complete field of contaminants, this discussion outlines options that would render the water system more complete in its ability to provide good potable water under most conditions.

**Potential treatment system improvements:**
These are the to-date identified possible improvements to the existing water treatment system that would allow it to deal with contaminants which it currently does not:

- Membrane Filtration
- Floculation
- Advanced Oxidation

These options have in the past been assessed in various levels of detail and need to be more thoroughly evaluated and ranked against several criteria to identify the top candidate(s). The following table shows the current subjective or qualitative status and understanding of these options.

| Potential Water Treatment Improvements | | | | | | |
|---|---|---|---|---|---|---|
| Improvement technology | Current understanding of the technology (1-10) | Treats Turbidity (1 to 10) | Treats Bio pathogens (1-10) | Treats Dissolved Organics (1-10) | Relative Cost (1-10) | Time to implement (1-10) |
| Membrane Filtration | ●●●●●●●●● | ●●●●●●●●●● | ●●●●● | - | ●●●●●●●● | ●●● |
| Floculation | ●●●●●●●●● | - | - | ●●●●●●●●●● | ●●●●●●●● | ●●● |

| | | | | | | |
|---|---|---|---|---|---|---|
| Advanced Oxidation | ? | ? | ? | ? | ? | ? |
| Other? | - | - | - | - | - | - |

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BRITISH COLUMBIA

# Guidelines for Ultraviolet Disinfection of Drinking Water

## Version 1.0 / First Published January 2022

### Ministry of Health

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## 1. Objective

To provide guidance on the reduction of pathogenic microorganisms[1] in drinking water using ultraviolet (UV) disinfection and the design, operation, and maintenance of UV equipment for drinking water applications.

## 2. Background and Regulatory Framework

The *Drinking Water Protection Act* (DWPA) (2001) and Drinking Water Protection Regulation (DWPR) (2003) specify water quality standards[2], monitoring schedules and recommended treatment aimed at reducing the risks from pathogens in drinking water. There are three main types of pathogens in drinking water that pose risks to human health: viruses, protozoa, and bacteria. The ingestion of these pathogens can result in short term illness and in some instances, serious long-lasting illnesses or even death.

To ensure the provision of clean, safe, and reliable drinking water in British Columbia, the multi-barrier approach is used. The multi-barrier approach is a system of procedures, processes and tools that collectively prevents or reduces the risk of contamination of drinking water from source-to-tap to reduce risks to human health[3]. Drinking water treatment is one component of the multi-barrier approach. Other components include source protection, operator training, water system maintenance, water quality monitoring and emergency response planning.

Section 5 of the DWPR requires that drinking water from a water supply system must be disinfected if the water originates from surface water, or groundwater that in the opinion of a Drinking Water Officer is at risk of containing pathogens. As "disinfection" is not defined in the DWPA or DWPR, technical guidance on disinfection is provided in this document for UV disinfection, the Design Guidelines for Drinking Water Systems in British Columbia (anticipated release date in 2022), the Guidelines for Pathogen Log Reduction Credit Assignment (2022) and in provincial drinking water treatment objectives.

Provincial drinking water treatment objectives are set out in the following guidance documents which are included in Part B to the Drinking Water Officers' Guide:

- Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia which provides a general overview of microbiological drinking water treatment objectives for surface water supplies; and

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[1] Health risks posed from chemical, physical, or radiological parameters are beyond the scope of this document.

[2] Schedule A of the Drinking Water Protection Regulation specifies bacteriological water quality standards for *Escherichia coli* (*E. coli*) and total and fecal coliform bacteria as no detectable bacteria per 100 mL of drinking water. Where more than 1 sample is collected in a 30 day period, the standard for total coliform is at least 90% of samples have no detectable total coliform bacteria per 100 mL and no sample has more than 10 total coliform bacteria per 100 mL.

[3] B.C. Office of the Provincial Health Officer (2019). Clean, Safe, and Reliable Drinking Water.

– Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia which specifies guidance on the treatment necessary to address microbiological contamination of groundwater sources and the assignment of subsurface filtration treatment credits.

Provincial drinking water treatment objectives for harvested rainwater are set out in the following guidance document which supplements the existing provincial treatment objectives for surface water supplies:

– Guidance for Treatment of Rainwater Harvested for Potable Use in British Columbia which provides a general overview of assessing the risks and treatment of rainwater for potable use.

All surface water supplies require disinfection; however, the requirement to disinfect groundwater supplies only applies to groundwater sources at risk of microbiological contamination. The Guidance Document for Determining Groundwater at Risk of Containing Pathogens (GARP) was developed to assist Health Authorities and water suppliers determine if a particular groundwater source requires disinfection. Risk factors that are discussed in the guideline include well construction, well location, aquifer characteristics and water quality results.

## 3. Purpose and Scope

This guideline provides provincial guidance[4] on the reduction of pathogenic microorganisms in drinking water using UV disinfection. The information in this document should be used by issuing officials during the approvals process, particularly with respect to the issuance of construction permits and operating permits under the *Drinking Water Protection Act* and the Drinking Water Protection Regulation. The information in this document can also be used by water suppliers, designers, and any other person or persons responsible for the planning and design of new water supply systems and when considering changes to existing systems.

This guideline is intended to supplement and not replace industry standards, guidelines, and best practices for UV disinfection of drinking water. More detailed information on the design and operation of drinking water systems can be found in the Design Guidelines for Drinking Water Systems in British Columbia.

## 4. Drinking Water Pathogens

The primary goal of drinking water disinfection is to reduce the presence of pathogens (disease-causing organisms) and associated health risks to an acceptable or tolerable level. The three main types of pathogens in drinking water that pose risks to human health are discussed below.

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[4] The guidance in this document is not legally binding. In the event of an inconsistency between the guidance in this document and the DWPA, DWPR, a drinking water operating permit or construction permit, or any direction of a Drinking Water Officer, the guidance in this document gives way to legally binding requirements.

## 4.1 Viruses

Viruses are submicroscopic infectious agents that replicate only inside the living cells of host organisms. UV disinfection can be used to reduce viruses in water, but the effectiveness of UV disinfection varies significantly depending upon the type of virus. For example, double-stranded DNA viruses, such as adenoviruses, are more resistant to UV than single-stranded RNA viruses, such as hepatitis A (Meng and Gerba, 1996; cited in Health Canada, 2011). Adenoviruses are excreted in large numbers by humans and are commonly found in untreated sewage and many surface water sources. Because some adenoviruses can cause illness, particularly in children and immunocompromised adults, adenovirus is sometimes used to establish UV disinfection requirements for viruses.

Other pathogenic viruses which pose risks to drinking water sources have also been studied for their UV disinfection requirements. Studies show that hepatitis A, poliovirus type 1, and various strains of coxsackievirus and rotavirus require a UV dose[5] ranging from 16 – 61 mJ/cm$^2$ from low pressure UV lamps for 4-log virus inactivation (see the Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses); of the viruses studied, rotavirus was the most resistant to UV disinfection after adenovirus.

Due to the high UV dosages required to reduce the concentration of enteric viruses in water, chemical disinfection (e.g. chlorination) is often the most appropriate treatment process for virus reduction.

## 4.2 Protozoa

Protozoa such as *Cryptosporidium* and *Giardia* are relatively large pathogenic single-celled microorganisms that, like enteric viruses, multiply only in the gastrointestinal tract of humans and other animals. *Cryptosporidium* oocysts and *Giardia* cysts[6] cannot multiply in the environment but can survive in water longer than intestinal bacteria. UV disinfection is the most effective means of oocyst and cyst inactivation.

## 4.3 Bacteria

Bacteria are single-celled microorganisms that can exist either as independent (free-living) organisms or as parasites (dependent on another organism for survival). Bacteria exhibit a range of UV sensitivity: many types are inactivated at low UV doses, while others (especially spore-forming bacteria) are considerably more resistant to UV disinfection than *Cryptosporidium* oocysts and *Giardia* cysts[7]. Bacterial reduction is normally sufficient if disinfection systems are designed to target virus reduction and as such, bacteria are not typically treated separately.

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[5] See Section 5 – UV Disinfection for more information on UV dose.

[6] Oocysts and cysts are the infective spore-like life stages of protozoa which are environmentally hardy and are shed by infected individuals in feces (CDC, 2020).

[7] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule. Also refer to Masjoudi *et al.* (2021), Sensitivity of Bacteria, Protozoa, Viruses, and Other Microorganisms to Ultraviolet Radiation.

# 5. UV Disinfection

UV light inactivates pathogens by damaging their nucleic acids (DNA and RNA) so that they cannot replicate and infect humans. The degree of pathogen inactivation depends upon the UV dose that is applied. For practical purposes, UV dose is expressed as the product of UV intensity, expressed in milliwatts per square centimeter of exposed area ($mW/cm^2$) and the amount of time that a microorganism is exposed to UV light in a reactor vessel (measured in seconds). The units of UV dose are expressed as millijoules per square centimeter ($mJ/cm^2$) which is equivalent to milliwatt seconds per square centimeter ($mW{\cdot}s/cm^2$).

UV dose delivery is influenced by the:

a) UV reactor design;
b) flow rate and fluid dynamics of water passing through the UV reactor;
c) UV transmittance (UVT) of the water being treated; and
d) UV intensity field within the reactor, which can be impacted by lamp sleeve transmittance and sleeve fouling, as well as lamp output, position, and aging.

Low pressure (LP) UV lamps (including low-pressure high-output lamps, LPHO) produce UV light at a single wavelength of 254 nm, which is an effective wavelength for the germicidal inactivation of pathogens. Medium pressure (MP) UV lamps produce polychromatic UV light which spans many wavelengths over the germicidal range (200 nm to 300 nm). Selection of lamp technology requires consideration of the reactor size, power demand and cost. Lamp and reactor selection (including dose monitoring strategy) should also consider monitoring and O&M requirements with respect to the water supplier's operational capacity. Refer to Section 11 – Monitoring Parameters and Section 12 – Equipment Verification and Calibration for more details.

The high efficacy and reliability of UV disinfection technology is well established within the drinking water sector. One of the advantages of using UV light for drinking water disinfection is that the disinfection by-products typically associated with the use of chemical disinfectants are not formed. However, unlike chlorine which can be used for both primary and residual disinfection, UV disinfection can only be used for primary disinfection because it does not have any residual disinfection capability.

UV dose requirements for the inactivation of *Cryptosporidium*, *Giardia,* and viruses, as developed by the U.S. EPA, are set out in Table 1. Note that due to the potential for particulate matter to interfere with UV disinfection, these dose requirements apply to post-filter applications of UV disinfection in filtered systems and to unfiltered systems that meet U.S. EPA filter avoidance criteria[8]. Particles in unfiltered water can interfere with UV disinfection in two ways: by decreasing the UVT, and by associating with microorganisms (including pathogens) and shielding them from UV light[9]. While the first effect can generally be captured by UVT monitoring, particle association with microorganisms can

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[8] 40 CFR 141.71.

[9] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

affect UV dose-response and cannot be predicted through monitoring. Particles larger than approximately 7–10 μm are able to enmesh and protect coliform bacteria from UV light, and smaller particles can shield viruses from UV exposure, reducing disinfection efficiency[10].

Due to this potential for interference by particles, pathogen log reduction credit assignment for drinking water systems in British Columbia should be based on:

- post-filter applications of UV equipment, or
- application of UV equipment to drinking water systems that use
  - a groundwater source at low risk of containing pathogens,
  - a 'GARP-viruses only' water source, or
  - a water source that has been granted a filtration exemption by a Drinking Water Officer.

For unfiltered systems that meet filtration exemption criteria, special consideration should be given to UVT and particle data when UV disinfection is being considered as part of the treatment process. Particle count analysis can be used to determine the level and type of pre- and post-treatment that should be provided; for example, if a source water experiences turbidity excursions with high counts of particles larger than 7 μm, at a minimum, cartridge filtration pre-treatment should be considered (i.e. cartridge filters with adequate pore size for particle removal).

The UV dose requirements in Table 1 account for the UV dose-response relationships of the target pathogens but do not address other significant sources of uncertainty in full-scale UV reactor applications due to the hydraulic effects of the UV installation, the UV equipment, and the monitoring approach. Due to these factors, UV reactors undergo validation testing to determine the operating conditions under which the reactors deliver the required UV dose for pathogen log reduction credit[11]. Reactor validation is discussed in Section 6.

[10] Templeton et al. (2008). Particle-associated viruses in water: Impacts on disinfection processes. Critical Reviews in Environmental Science and Technology, 38:3, 137-164.

[11] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

### Table 1: UV Dose Requirements (mJ/cm$^2$) for the Inactivation of *Cryptosporidium*, *Giardia* and Viruses[12]

| Target Pathogen | Log Inactivation [a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0.5** | **1.0** | **1.5** | **2.0** | **2.5** | **3.0** | **3.5** | **4.0** |
| *Cryptosporidium* | 1.6 | 2.5 | 3.9 | 5.8 | 8.5 | 12 | 15 | 22 |
| *Giardia* | 1.5 | 2.1 | 3.0 | 5.2 | 7.7 | 11 | 15 | 22 |
| Viruses (based on adenovirus) [b] | 39 | 58 | 79 | 100 | 121 | 143 | 163 | 186 |

[a] In the U.S., the UV dose values in Table 1 are applicable to post-filter applications of UV in filtered systems and to unfiltered systems that meet filter avoidance criteria under Title 40 of the U.S. Code of Federal Regulations (40 CFR 141.71). In B.C., the UV dose values in Table 1 are recommended for post-filter application of UV, or application of UV equipment to drinking water systems that use a groundwater source at low risk of containing pathogens, a 'GARP-viruses only' water source, or a water source that has been granted a filtration exemption by a Drinking Water Officer.

[b] Typically, chemical disinfection is used for virus inactivation due to the high UV dosages required.

### Adenovirus and Rotavirus

The UV dose requirements for virus inactivation in Table 1 are based on the log inactivation of adenovirus, which is used by some jurisdictions as a target pathogen for establishing UV virus inactivation requirements. In British Columbia, depending upon the results of a source water assessment from the water supplier or other studies conducted by the water supplier, a Drinking Water Officer has the discretion to base virus log inactivation requirements on either adenovirus or rotavirus.

For drinking water sources that are considered to be vulnerable to human fecal contamination[13] and based on the UV dose requirements set out in Table 1, a 40 mJ/cm$^2$ UV dose would provide 0.5-log inactivation of viruses based on adenovirus. Under such circumstances, two or more forms of treatment (e.g. chemical disinfection and UV disinfection), would be necessary to provide additional virus inactivation.

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[12] 40 CFR 141.720(d)(1) and USEPA (2006), Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

[13] The DWO may use their discretion to determine whether a drinking water source is at risk of fecal contamination. Key considerations could include hydraulic connection to a known human wastewater source (including onsite sewage) and elevated presence of fecal indicators (e.g. *E. coli* > 20 colony forming units/100 mL).

For drinking water sources that are considered to be at low risk from human fecal contamination, a Drinking Water Officer may decide that rotavirus is a more appropriate pathogen upon which to base virus inactivation requirements.

Unlike for adenovirus, standardized UV dose requirements have not been established for different levels of rotavirus inactivation. Some studies[14] have reported that 3 and 4-log rotavirus inactivation require UV doses greater than 40 $mJ/cm^2$. Until the UV dose response requirements for rotavirus are formally developed using modern testing protocols (Bolton *et al.*, 2015), a 40 $mJ/cm^2$ UV dose has been conservatively assigned a 2-log virus inactivation credit in British Columbia based on rotavirus inactivation.

## 6. Reactor Validation

UV reactors for medium and large water systems undergo validation testing to determine the operating conditions required to deliver a validated UV dose. Validation testing is based on reactor type/model and is typically conducted by a recognized third party at a facility specifically designed for reactor validation. There are no requirements for the periodic revalidation of a reactor once it has been validated.

> Note: UV reactors for small water systems are typically certified based on a recognized certification standard. Reactor certification is not the same as reactor validation as the certification and validation processes are not equal (e.g. the factors associated with experimental uncertainty – including UV lamp fouling/aging and the differences in UV sensitivity between challenge organisms and target pathogens – are not accounted for in reactor certification). Reactor certification is discussed in Section 7.

There are several different protocols that are used to validate UV reactors. The following validation protocols are recognized by the Province of British Columbia:

- The German guideline DVGW W294;
- The Austrian standard ÖNORM M 5873; and
- The U.S. EPA UVDGM.

These protocols validate a UV reactor for a reduction equivalent dose (RED; also called the reduction equivalent fluence or REF) based on biodosimetry testing under variable flowrate, UVT and UV intensity settings. Biodosimetry testing is described in Section 6.1.

Validation testing should account for:

a) UVT or absorbance of the water;

[14] Health Canada (2019). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses.

b) Lamp fouling and aging factors[15];
c) Measurement uncertainty of online sensors;
d) UV dose distributions arising from the velocity profiles through the reactor;
e) Failure of UV lamps or other critical components;
f) Inlet and outlet piping or channel configurations of the UV reactor;
g) RED bias (applicable to UVDGM-validated reactors); and
h) Action spectra bias (applicable to UVDGM-validated reactors).

## 6.1 Biodosimetry Testing

Biodosimetry testing is used to determine the reduction equivalent dose (RED) of a UV reactor by measuring the inactivation of a challenge microorganism after exposure to UV light in the reactor and comparing the results to the dose-response curve of the challenge microorganism determined by bench-scale collimated beam testing. Challenge microorganisms are described in more detail in Section 6.2.

Biodosimetry testing is necessary because it is difficult to predict full-scale reactor disinfection performance based on modeling or bench-scale testing. Biodosimetry testing includes the following steps:

1. **Collimated Beam Testing** – A collimated beam apparatus which produces a precise, uniform UV light output at a wavelength of 254 nm is used to determine the UV dose-response curve of a challenge microorganism. Water samples containing the challenge microorganism are irradiated in a bench-scale laboratory test and the concentrations of viable microorganisms are measured before and after exposure to various doses of UV light. A dose-response curve is graphed by plotting the log inactivation of the challenge microorganism versus the applied dose. The applied dose is calculated based on measured UV intensity, the UV absorbance of water, the depth of the water and the exposure time of the challenge microorganism to the collimated beam. The UV dose-response curve is a measurement of the sensitivity of the challenge microorganism to UV light and is unique to the microorganism. Note that the collimated beam apparatus uses a low-pressure (LP) lamp, and correction factors must be used to adapt the dose-response curves for use with medium pressure (MP) lamps (see Section 6.3)

2. **Full-Scale Reactor Testing** – Log inactivation data are collected from full-scale reactor testing for specific operating conditions (i.e. flow rate, UVT and UV intensity) using the same challenge microorganism as in the collimated beam tests.

3. **Reduction Equivalent Dose** – A reduction equivalent dose (RED) is estimated by interpolating the log inactivation results from full-scale reactor testing onto the UV dose-response curve

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[15] Note: If the source water at the proposed installation site has elevated inorganic constituents (iron, manganese, hardness) and pH, lamp fouling and aging factors may need to be determined during on-site commissioning. This may impact cleaning frequencies and overall project cost. Refer to Sections 9.2 and 9.23.

from collimated beam testing. RED values are specific to the challenge microorganism used for collimated beam testing and the validation test conditions for full-scale reactor testing.

4. **Pathogen Specific Validated Dose** (applicable to UVDGM only) – The RED value is adjusted for experimental uncertainties and biases using a pathogen-specific validation factor (VF) to produce a pathogen-specific validated dose:

**Validated Dose = Reduction Equivalent Dose (RED) / Validation Factor (VF)**

Further information on biodosimetry testing can be found in the Section 5.2 of the U.S. EPA UVDGM.

## 6.2 Challenge Microorganisms

Depending upon the validation protocol chosen and the target pathogen (*Cryptosporidium*, *Giardia*, adenovirus, or rotavirus), different challenge microorganisms may be used. Challenge microorganisms are non-pathogenic surrogates and include bacteria-specific viruses such as MS2 bacteriophage and bacterial spores such as *Bacillus subtilis*. Challenge microorganisms are set out in Table 2 for each of the validation protocols recognized by the Province of British Columbia. Section 5.3 of the UVDGM provides information on factors to consider during challenge microorganism selection.

**Table 2: Challenge Microorganisms**

| Validation Protocol | Challenge Microorganisms |
|---|---|
| DVGW W294 | Bacillus subtilis ATCC #6633 |
| ÖNORM M 5873 | Bacillus subtilis ATCC #6633 |
| UVDGM | MS2 Bacteriophage ATCC #15597-B1<br>Bacillus subtilis ATCC #6633<br>Or other (see Table 5.2 in the U.S. EPA UVDGM) |

ATCC – American Type Culture Collection

For the DVGW and ÖNORM validation protocols, the challenge microorganism *B. subtilis* is used to confirm that the minimum RED of 40 $mJ/cm^2$ is delivered by the reactor. The UVDGM validation protocol allows for different REDs to be targeted, which allows for more flexibility in terms of treatment objectives and operational needs (for example, the UV system may be designed for 1-log reduction of *Cryptosporidium* and *Giardia*, which will reduce power and operational costs compared to a DVGW-validated reactor). Furthermore, the 2020 U.S. EPA document "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems" (discussed in Section 6.4) recommends using two or more challenge microorganisms with different UV dose-response, such as MS2 and T1UV phage.

## 6.3 Considerations for UVDGM-validated Reactors

For UVDGM-validated reactors, ideally the challenge microorganism should have the same UV dose-response (at 254 nm) and action spectra (dose-response over the germicidal range of UV wavelengths) as the target pathogen. In practice, both the UV dose-response and the action spectra of challenge microorganisms and target pathogens differ. Correction factors must be applied, otherwise the log reduction of the target pathogen may be overestimated.

The RED bias is defined as the ratio of the RED measured using the challenge microorganism used to validate the reactor and the RED that would have been delivered to the target pathogen. If the challenge microorganism has the same UV dose-response as the target pathogen, the RED bias is 1.0. If the challenge microorganism is more resistant to UV light than the target pathogen, the RED bias is greater than 1.0. Conversely, if the challenge microorganism is more sensitive to UV light than the target pathogen, the RED bias is less than 1.0.

Under the UVDGM validation protocol, the RED bias factor is a correction factor that accounts for the difference in the UV dose-response (at 254 nm) of the challenge microorganism and target pathogen. More information, including RED bias values based on UVT, log reduction targets, and challenge microorganism UV sensitivity, can be found in the U.S. EPA UVDGM.

The action spectra correction factor (ASCF) accounts for differences in spectral response. The ASCF is applicable to medium pressure UV reactors and other lamps which emit UV light at wavelengths other than 254 nm (for example, LEDs). Action spectra bias is particularly an issue as many challenge microorganisms are more susceptible to inactivation from low-wavelength UV light (<240 nm) than target pathogens, which leads to an overestimation of UV performance. Furthermore, most UV sensors cannot accurately measure intensity in the low-wavelength range, although low-wavelength sensors are now available[16]. Tabulated ASCFs for different challenge microorganisms and target pathogens can be found in the U.S. EPA UVDGM; however, these values do not account for factors which may lead to underestimation of the delivered UV dose (e.g. UV transmittance of the quartz sleeve, changes in water quality compared to the validation water, and lamp aging/fouling). The WRF Report #4376 "Guidance for Implementing Action Spectra Correction with Medium Pressure UV Disinfection" (2015)[17] provides details on different ASCF options, including:

- updated generic tabulated ASCFs;
- development of reactor-specific or site-specific ASCFs using computational fluid dynamics and UV intensity field models (CFD-I); and
- development of reactor-specific or site-specific ASCFs through validation tests.

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[16] USEPA (2020). Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

[17] Table ES.1.

Additional information about ASCF calculation using low-wavelength data is set out in the U.S. EPA 2020 document "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems".

There are two other important considerations for UVDGM-validated reactors:

- because the action spectra of *Cryptosporidium* and *Giardia* are statistically similar, the ASCFs for *Cryptosporidium* can be directly used for *Giardia*[18]; and
- because adenovirus was used as the target pathogen for viruses, there are no tabulated RED bias or ASCF values for rotavirus. Appropriate correction factors should be discussed with an issuing official.

## 6.4 Innovative Approaches for Dose Monitoring and UVDGM Reactor Validation

New approaches and procedures for dose monitoring and UVDGM reactor validation are set out in the 2020 U.S. EPA document "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems" (also referred to as the "Innovative Approaches" document). These approaches and procedures include:

- Microbial methods and dose-response QA/QC bounds for commonly used microbial surrogates in UV reactor validation;
- Approaches for the development of calculated UV dose monitoring algorithms with improved accuracy that eliminate the need for RED bias factors;
- Approaches for the development of UV dose monitoring algorithms that do not require an online UV transmittance monitor for simplified UV system operations;
- For UV reactors equipped with medium pressure UV lamps, implementation of "low wavelength" UV sensors and approaches for the development of UV dose monitoring algorithms that account for the disinfection associated with wavelengths below 240 nm;
- Criteria for the development of a robust validation test matrix, monitoring algorithm goodness of fit and QA/QC requirements, and standardized approaches for defining the validated range of UV reactors;
- Target UV doses for 4.5, 5.0, 5.5 and 6.0 log inactivation of *Cryptosporidium*, *Giardia* and viruses for UV applications requiring higher levels of disinfection than the maximum 4.0 log provided by the UVDGM;
- General validation and data analysis procedures that are commonly implemented in UV reactor validation but are not explicitly documented in the UVDGM; and
- Modifications to the operating recommendations of the UVDGM to improve the accuracy of UV dose-monitoring with the water treatment application.

[18] WRF (2015) Report #4376 - Guidance for Implementing Action Spectra Correction with Medium Pressure UV Disinfection.

The approaches and procedures in the "Innovative Approaches" document are presented for consideration when applying UV disinfection for the inactivation of *Cryptosporidium*, *Giardia*, and viruses, and should not be construed as a replacement or revision to the UVDGM.

## 6.5 Validation Certificates and Validation Reports

Validation Certificates and Validation Reports document validated operating conditions for UV reactors. This documentation allows an issuing official to assess whether a UV reactor is appropriate for the specified application and it must be provided to the issuing official during the construction permit application review and approvals process.

Validation Certificates are used to document validated operating conditions for reactors that have been validated using the DVGW Guideline and the ÖNORM standard. Validation Certificates specify minimum UV intensity and the maximum flowrate through the reactor.

Validation Reports are used to document validated operating conditions for reactors that have been validated using the U.S. EPA UVDGM protocol. Validation Reports provide detailed documentation of all validation testing results and should include all elements of the validation test plan and a summary of the field-verified UV reactor properties. Validation Reports should also include the reactor's validated dose or range of validated doses, validation factors, log reduction credits for target pathogens, validated operating conditions, and the UV intensity set point(s) if the UV intensity set point monitoring/control strategy is used or the dose monitoring equation if the calculated dose monitoring/control strategy is used.

More information on validation reports including checklists for report content and review, can be found in Section 5.11.3 of the U.S. EPA UVDGM, as well as in Section 2.9 of the U.S. EPA 2020 "Innovative Approaches" document.

## 6.6 Validated Operating Conditions

To receive pathogen log reduction credits, UV reactors should operate within their validated operating conditions (also referred to as the "validation envelope"). These operating conditions should be considered during validation testing and should be explicitly tested or fall within the range of conditions tested.

Validated operating conditions should include flow rate, UV intensity as measured by a UV sensor, UV lamp status and UVT if a calculated dose control strategy is used (see Section 8.1). Alarms should activate when the measured UV intensity is below the validated UV intensity set point or when the calculated UV dose is below the dose required to meet the pathogen log reduction target. Refer to Section 13 for Alarm Conditions.

With the approval of the issuing official, UV reactors may be permitted to operate outside of their validated range where the UVT is above the validated range and/or the flow rate is less than the validated range, as long as the reactor can operate safely (i.e. without overheating).

## 6.7 On-site Validation

UV reactors are typically validated off-site at specialized third-party testing centres or at a UV manufacturer's facilities. On-site validation is used when:

- A UV reactor's validated operating conditions (previously obtained through validation testing) do not encompass the specified design criteria for the proposed installation (for example, an extended UVT, flow rate, or UV intensity/lamp output range);
- A design change deviating from previous validation is being sought for the reactor (e.g. new lamp or sleeve type); or
- Existing inlet/outlet piping configurations are constrained and cannot follow standard installation.

Before choosing on-site validation, the water supplier should contact the issuing official to discuss the development of a work program that is acceptable to the issuing official.

The work program for on-site validation should include the following tasks:

1) The collection of background information to support the validation of the reactor;
2) The development of a work plan including high-level schedule, subsequent tasks, and budget for presentation to and review by the issuing official;
3) Where applicable, an initial site visit to review reactor installation and operation, and to identify any issues that could potentially impact on-site validation;
4) The development of a test plan to establish validated operating conditions for the reactor. Multiple test conditions should be proposed which adequately cover the range of operating conditions to be validated in terms of:
    - Flow rates;
    - UVT values; and
    - Lamp power and configuration.

    The test plan should also include consideration of:
    - The challenge microorganism selected;
    - The target pathogen (e.g. *Cryptosporidium, Giardia*, rotavirus, or adenovirus);
    - The preparation of water to be used in the validation test (including assessing the need for chlorine quenching, methods to adjust UVT for the testing range, and mixing requirements for the challenge microorganism and/or chemical addition);
    - A plan for the safe discharge of the validation test water (may require permits);
    - The inclusion of appropriate QA/QC samples; and
    - Whether sensor linearity needs to be established or extended (i.e. if UVT targets extend beyond the normal validated range).
5) On-site validation testing using the test plan including:
    - Equipment set-up and functional testing to verify the operation of the test systems (including power consumption);
    - UV sensor testing (including reference sensor tests and duty UV sensor functional testing to characterize duty UV sensor readings);
    - Biodosimetry testing; and

   - Assessment of the site-specific aging/fouling factor.

6) A review meeting to discuss the on-site validation work with the water supplier and the issuing official and to present the draft report; and
7) The production of a final report that documents the work that was completed under the work program. The final report should be submitted to the issuing official.

On-site validation should be conducted by an independent third party that has the necessary competencies (knowledge, skills, and experience) to do the work. Individuals qualified for such oversight include professional engineers experienced in testing and evaluating UV reactors and scientists experienced in the microbial aspects of biodosimetry. The independent third party should provide oversight to ensure that validation testing and data analyses are conducted in a technically sound manner and without bias. A person independent of the UV reactor manufacturer should oversee the validation testing.

## 7. Reactor Certification

Some UV reactors are certified using NSF/ANSI Standard 55 which establishes minimum requirements for the reduction of microorganisms using ultraviolet microbiological water treatment systems. NSF Standard 55 also specifies the minimum product literature and labeling information that a manufacturer must supply to authorized representatives and system owners, as well as the minimum service-related obligations that the manufacturer must extend to system owners.

NSF-certified equipment complies with the standards and procedures imposed by NSF including extensive product testing and material analyses. Equipment manufacturers are subjected to unannounced plant inspections and regular product retesting.

Small drinking water systems typically use UV disinfection systems that are certified to NSF Standard 55. There are two types of systems certified under the Standard: Class A systems and Class B systems.

Class A systems are designed to inactivate and/or remove microorganisms, including bacteria, viruses, *Cryptosporidium*, and *Giardia* from contaminated water. Class A systems are intended for visually clear water and are not intended for the treatment of water that has obvious contamination, such as raw sewage, or for the conversion of wastewater to drinking water[19]. Class B systems are designed for supplemental bacterial treatment of disinfected public water or other drinking water that has been tested and deemed acceptable for human consumption.

It is recommended that NSF Standard 55 Class A certified systems should only be used for small water systems. Water systems that serve more than 500 people in any 24-hour period should use UV disinfection systems that have been validated using one of the validation protocols listed in Section 6. NSF Standard 55 Class B certified systems should not be used for the production of potable water.

[19] NSF/ANSI 55 - 2019 Ultraviolet Microbiological Water Treatment Systems.

Class A systems are certified to deliver a UV dose that is at least equivalent to 40 mJ/cm$^2$ at the alarm set point when the system is tested in accordance with the Standard. Recommended maximum pathogen log reduction credits for NSF Standard 55 Class A devices are listed in Table 4. An issuing official has discretion in assigning pathogen log reduction credits based on an assessment of risk for any specific application.

NSF Standard 55 Class A certified systems should have the following:

a) a dedicated power line;
b) a built-in flow restrictor or automatic fixed flow rate control;
c) a UV intensity sensor to detect when the UV intensity at the sensor is below the required minimum;
d) a visual alarm, audible alarm or a system that terminates the discharge of water when the UV system is not operating effectively;
e) an emergency shut-off valve; and
f) a performance data sheet that includes the rated service flow of the reactor in litres/minute or litres/day. Class A systems are typically available for flow rates ranging from 37.9 to 114 litres/minute.

The NSF Standard 55 does not require Class A certified systems to have a UV monitor, which provides an online readout of UV intensity and/or dose delivered. However, provision of a UV monitor and a reference UV sensor may be requested by the issuing official to allow for monthly calibration verification checks of the duty UV sensor (refer to Section 12 – Equipment Verification and Calibration for more information).

Certification information for NSF/ANSI 55 Ultraviolet Microbiological Water Treatment Systems is available online via NSF's website. The information identifies manufacturer name, brand name/trade name/model, flowrate, and disinfection performance claim for Class A and Class B systems. The following organizations have also been accredited in Canada to certify UV reactors as meeting NSF/ANSI Standard 55:

- Water Quality Association (WQA);
- International Association of Plumbing & Mechanical Officials (IAPMO); and
- CSA Group.

# 8. Dose Monitoring/Control Strategies

There are two main dose monitoring/control strategies that are commonly used by UV equipment manufacturers: calculated dose and UV intensity set point.

## 8.1 Calculated Dose

The calculated dose control strategy uses a dose monitoring equation to estimate UV dose based on the operating conditions of the UV reactor (e.g. measured flow rate, UV intensity and UVT[20]). The calculated dose is divided by the reactor's Validation Factor and the resulting validated dose is compared to the required dose for the target pathogen and the targeted pathogen log inactivation level. When the validated dose is less than the required dose for the targeted pathogen log inactivation level, the produced water would be considered off-specification and an alarm condition should be activated.

This control strategy is only available for reactors validated using the U.S. EPA UVDGM protocol. Development of the dose monitoring equation is described in the UVDGM (Chapter 5) as well as in the EPA 2020 "Innovative Approaches" document.

## 8.2 UV Intensity Set Point

The UV intensity set point strategy is available under all validation protocols listed in Section 6. This strategy relies on one or more set points for UV intensity that are established during validation testing. These set points achieve a specific UV dose based on a maximum flowrate and either one or multiple minimum UV intensity values.

The simplest approach is "single set point" operation, which uses one UV intensity set point which achieves the targeted UV dose at a maximum flowrate. NSF 55 Class A certified systems operate with a "single set point" strategy. A "variable set point" approach validates multiple set point pairs of minimum UV intensity which are associated with different flow rates. During UV reactor operation, the measured UV intensity must meet or exceed the set point(s) to ensure the delivery of the required dose. UV reactors must also be operated within validated operating conditions for flow rate and lamp status.

UVT does not need to be monitored separately to confirm the UV dose delivered since the UV intensity readings account for changes in UVT. However, UVT should be monitored on a periodic basis (e.g. with grab samples) to confirm that it is within the range of validated operating conditions.

[20] UVT may not be required for some calculated dose monitoring approaches. See USEPA (2020), Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

## 9. Design and Installation Considerations

UV equipment design and installation should consider:

1. **Source Water Characterization Data** – For surface water and GARP water supplies, filtration should be installed upstream of UV disinfection to ensure that UV reactor performance is not compromised due to poor or changing water quality and UV reactors continuously operate within their validation envelope or range of certified operating conditions. If filtration is not installed upstream of UV disinfection, a water supply system must be approved for filtration exemption and meet the conditions for exemption set out in the 'Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia'.

   For a water supply system that meets the conditions for filtration exemption, source water characterization data should identify seasonal changes and annual trends in drinking water quality that may affect UV reactor performance (particularly for UVT). Ideally, at least two years of data should be used to inform reactor design decisions.

   If a MP reactor using a calculated dose control strategy is proposed which uses wavelengths shorter than 240 nm in the dose monitoring equation, low wavelength UVT (at ~220 nm) should also be characterized in the source water[21]. UVT data below 240 nm is not required for MP systems if ASCFs are applied per WRF Project 4376, because the ASCF values assume no dose delivery below 240 nm.

2. **Water Quality Requirements for Water Entering a UV Reactor** – UV reactor performance is affected by UVT, particle content, algae, upstream water treatment processes, and constituents in the water that foul reactor components. Water entering a UV reactor should meet water quality requirements specified by the UV equipment manufacturer and should ideally be of sufficient quality to minimize cleaning requirements.

   If the UV equipment manufacturer has not specified water quality requirements for water entering the reactor, the values in Table 3 are recommended. Different values for these parameters may be acceptable to an issuing official if:
   - The reactor was validated for different values (e.g. for an extended UVT range);
   - Experience with similar water quality and reactors demonstrates that adequate treatment is provided; or
   - For elevated inorganic constituents (iron, manganese, hardness) or pH, the combined aging and fouling factor (CAF) is determined during on-site commissioning. Refer to point 23 – Fouling/Aging Factors.

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[21] USEPA (2020). Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

**Table 3: Recommended Water Quality for Water Entering a UV Reactor**

| Parameter [a] | Value |
|---|---|
| Turbidity | < 1.0 NTU |
| Hardness | < 120 mg/L |
| Iron | < 0.3 mg/L |
| Manganese | < 0.05 mg/L |
| Hydrogen sulphide (if odour present) | Non-detectable |
| Total suspended solids (TSS) | < 10 mg/L |
| pH | 6.5 to 9.5 |
| Total coliform | < 1000/100 mL |
| UVT [b] | > 75 % |

[a] Parameters from 10 State Standards (2018), except [b].
[b] UVT for fair water quality, U.S. EPA Guidance Manual on Alternative Disinfectants and Oxidants (1999).

3. **Design Flow Rate** – UV facility design should consider the average, maximum and minimum flow rates that the UV equipment will experience. Long-term population projections should be considered as well as current and long-term maximum day demand.

4. **Maximum Flow Rate and Pressure** – Design and installation should ensure that the maximum rated flow rate and pressure cannot be exceeded for the UV equipment.

5. **Inlet and Outlet Piping Configuration** – Inlet and outlet piping to a UV reactor should result in UV dose delivery that is equal to or greater than the UV dose delivered when the UV reactor was validated for the targeted pathogen log inactivation level. The piping configuration used for validation is usually included in the Validation Report. The issuing official may request a preferred piping configuration as recommended in sections 3.6.2 and 4.1.1 of the U.S. EPA UVDGM.

6. **UV Intensity Sensor** – UV reactors should have a UV intensity sensor to verify that sufficient UV light is being delivered to the reactor. Water should not be able to flow through the reactor when the reactor lamps are off or not fully energized unless the reactor was validated with some of the lamps off and the reactor is operating within its validation envelope.

7. **Temperature Sensor and Control** – UV reactors should have a temperature sensor to monitor water temperature within the reactor. If water temperature exceeds the recommended operating range for the reactor, the reactor should shut off to minimize the potential for reactor lamps to overheat. Some reactors may require provisions for cooling water which should be considered during design.

8. **Lamp Status** – UV equipment should have a lamp status indicator that indicates whether a UV lamp is on or off.

9. **Lamp Sleeve** – UV assemblies should be insulated from direct contact with influent water by a natural or synthetic quartz lamp sleeve. The quartz lamp sleeve type used in day-to-day equipment operation should be the same type as was used for equipment validation.

10. **UV Assembly Inspection and Cleaning** – UV assemblies should be accessible for visual observation, cleaning and replacement of the UV lamps, lamp sleeves and sensor window/lens. Lamp sleeves may be cleaned via online mechanical cleaning (with an automated wiper), online mechanical-chemical cleaning (automated wipers with a cleaning solution), or offline chemical cleaning at prescribed frequencies. If online cleaning mechanisms are included, components (wipers, motors/drives, cleaning solution reservoirs, etc.) should also be accessible for observation and maintenance.

11. **Power Quality** – UV equipment installation must consider local power quality. A power quality assessment should be conducted for areas where there are known power quality problems or for remote areas where power quality is unknown. Where power quality is identified as a concern, provisions should be made for power quality monitoring and/or power conditioning, as well as sufficient emergency power supply and/or uninterruptible power supply (UPS) to fully operate the UV equipment.

12. **Lamp Power** – Under normal operating conditions, UV lamps should not run at or near 100% power. UV reactors should be sized appropriately, such that lamp power is efficient under normal operating conditions, and that normal water quality fluctuations do not trigger operation of standby reactors.

13. **Reactor Bypasses** – UV reactor bypasses should not be installed unless specifically authorized by a Drinking Water Officer for the provision of emergency water supply. Adequate safeguards should be put in place to protect public health.

14. **Off-Specification Events** – In the event that a UV reactor malfunctions, loses power, or ceases to provide the required level of disinfection, there should be a feature that causes an alarm to sound or ensures that water from the affected reactor is prevented from entering the distribution system. Refer to Section 14 – Off-Specification Water for more details.

15. **Audible Alarm** – For UV equipment with an audible alarm, the alarm should sound in the building or structure where the UV equipment is installed or at a location where an operator is normally present.

16. **Critical Alarm Conditions** – For UV equipment with an automatic shut-off, UV reactors should automatically shut down under critical alarm conditions (e.g. multiple lamp/ballast failures, low liquid level, or high temperature) to prevent damage to the UV equipment. These alarm conditions should be considered during design to reduce the potential for downstream

pressure transients in the distribution system during sudden shut-offs. For treatment facilities with duty and standby reactors, duty reactors should automatically switch to standby reactors during critical alarm shutdown to minimize disruption to the drinking water supply.

17. **On-line Lamp Breaks** – On-line lamp breaks occur when a lamp and lamp sleeve break while water is flowing through a UV reactor. On-line lamp breaks may be caused by debris, improper lamp orientation, loss of water flow and temperature increases, pressure related events, lamp handling and maintenance errors, and UV reactor manufacturing problems. Preventative measures should be considered, and emergency response procedures to protect customers from mercury and broken glass should be documented in the Emergency Response and Contingency Plan for the drinking water system. More information on UV lamp breaks including preventative measures for on-line lamp breaks can be found in Appendix E to the U.S. EPA UVDGM.

18. **Equipment Component Installation and Replacement** – When UV equipment components are installed or replaced, they should be the same as the components used for equipment validation and/or certification unless the UV equipment was revalidated or recertified. When lamps are replaced from a lamp row or group, the lamp with the longest run time should be moved closest to the UV sensor, and the new lamp installed in the remaining space.

19. **Automated/Unattended Operation** – For UV equipment with automated/unattended operation:

    a. **Real-Time Monitoring** – Real-time monitoring should be used to continuously monitor equipment operation at the remote location. UV dose, alarm history, lamp hours and any other parameters necessary for the proper operation of the equipment should be recorded. A historian function should be included which retains instrumentation and control data for unattended periods (i.e. overnight) for operator review;

    b. **Self-Diagnostic Testing** – UV equipment should have a self-diagnostic test feature that will not disengage the auto shut-off valve until proper disinfection is occurring; and

    c. **Automatic Shut-off Valves** – Automatic shut-off valves should be maintained and checked at the frequency recommended by the equipment manufacturer to ensure reliable operation. Maintenance records should be available for inspection by a Drinking Water Officer when requested.

20. **Equipment Redundancy** – To avoid interruption of flow and where physically possible, a minimum of two UV reactor trains should be installed at treatment facilities that have continuous flow requirements. Full redundancy should consider the effect of shutting down the largest UV reactor for routine maintenance and for changing UV lamps. Redundancy should also consider the effects of equipment failure and the time required for equipment repair. Additional replacement components for the reactor and monitoring systems should be stored onsite; refer to Section 6.3.3 of the UVDGM for a recommended spare parts inventory.

21. **UV Equipment Software** – UV equipment software should be compatible with the SCADA[22] software used for the drinking water system.

22. **Real-time UVT Monitoring** – Real-time UVT monitoring should be used for UV disinfection systems that use the calculated dose control strategy. The provision of multiple UV analyzers should be considered for redundancy, and to allow for one analyzer to be taken out of service for calibration and maintenance.

23. **Fouling/Aging Factors** – Sleeve fouling, sleeve aging, lamp aging, and UV sensor window fouling (if applicable) affect long-term UV reactor performance. Combined aging and fouling factors (CAF) are often used to size a UV reactor for a particular application (i.e. to make sure that the lamp output can still meet the targeted log inactivation, even with an estimated amount of fouling and aging on sleeves and sensors).

    If a higher (less conservative) CAF is used and the water being treated causes heavy fouling, the reactor will produce off-spec water unless the cleaning frequency is increased (i.e. more wiper cycles or offline chemical cleans). In this case, an on-site fouling study should be conducted to inform the cleaning schedule; refer to Section 3.4.5 of the U.S. EPA UVDGM for details on fouling study considerations. Alternatively, a lower (more conservative) CAF could be used during UV equipment design.

    Warranties from UV vendors should be based on the CAF measured in the field by UV sensors.

24. **UV-LED Equipment** – Ultraviolet light-emitting diodes (UV-LEDs) are emerging as a viable technology for drinking water disinfection. Compared to conventional mercury UV lamps, UV-LED lamps are mercury-free, compact, robust, suffer minimal damage from repeated cycling, have longer life and reach full power faster. These advantages, along with virtually instantaneous start-ups and tunable wavelengths, offer great flexibility in UV-LED reactor design. Many applications of UV-LED reactors have focused on small-scale, point-of-use systems due to cost and power considerations (Jarvis *et al.* 2019); however, some larger-scale applications have been developed and approved for installation under the U.S. EPA UVDGM validation protocol.

    To be considered for pathogen log reduction credit assignment, UV-LED equipment for drinking water disinfection should be validated under an approved validation protocol or have NSF Standard 55 Class A certification (see Section 7 – Reactor Certification).

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[22] SCADA (Supervisory Control and Data Acquisition) is a process control system that enables drinking water treatment operators to collect data from process sensors and/or to control equipment manually or automatically. The SCADA system may be accessible in the treatment facility and/or from a remote location.

## 10. Pathogen Log Reduction Credit Assignment

In order for a UV disinfection system to receive pathogen log reduction credits, it should be validated or certified by an accredited or independent third party based on a validation protocol or certification standard recognized by the Province of British Columbia. Independent third-party oversight ensures that validation and/or certification testing, and data analyses are conducted in a technically sound manner and without bias. A person independent of the UV equipment manufacturer should oversee the validation and/or certification testing.

Full-scale UV reactor validation and/or certification testing should document the operating conditions (maximum flow rate, UV intensity, UV lamp status (on/off) and minimum UVT) under which the reactor can deliver the required UV dose to achieve the required pathogen log reduction.

Pathogen log reduction credit assignment is based on:

1. Post-filter applications of UV equipment, or application of UV equipment to drinking water systems that use:
    a. A groundwater source at low risk of containing pathogens;
    b. A 'GARP-viruses only' water source; or,
    c. A water source that has been granted a filtration exemption by a Drinking Water Officer.
2. The UV equipment being fully operational; and
3. The recommended pathogen log reduction credit assignment criteria being met (see Section 7 of the 'Guidelines for Pathogen Log Reduction Credit Assignment').

Pathogen log reduction credit assignment is set out in Table 4 for the validation protocols and certification standards that are recognized by the Province of British Columbia.

### Table 4: Pathogen Log Reduction Credit Assignment

| Validation Protocol or Certification Standard | Minimum UV Dosage [a] | Maximum Pathogen Log Reduction Credits Assigned [b, c] | | |
|---|---|---|---|---|
| | | *Cryptosporidium* Oocysts | *Giardia* Cysts | Viruses [d] |
| DVGW W294 | RED = 40 mJ/cm² | 3 | 3 | 0.5 or 2 |
| NSF Standard 55 (Class A Systems only) | 40 mJ/cm² | 3 | 3 | 0.5 or 2 |
| ÖNORM M 5873 | RED = 40 mJ/cm² | 3 | 3 | 0.5 or 2 |
| UVDGM | Validated dose ≥ required dose for target pathogen log inactivation [e] | Determined on a case by case basis | Determined on a case by case basis | Determined on a case by case basis |

RED = Reduction Equivalent Dose. May also be called the REF (Reduction Equivalent Fluence).

[a] Validated reactors establish a RED for a specific organism (e.g. an MS2 RED or a *B. subtilis* RED). Similarly, NSF Standard 55 Class A certified systems are designed to deliver a UV dose that is at least equivalent to the MS2 bacteriophage dose-response at 40 mJ/cm² when the systems are tested in accordance with the Standard.

[b] Pathogen log reduction credit assignment is based on post-filter applications of UV equipment, or application of UV equipment to drinking water systems that use a groundwater source at low risk of containing pathogens; a 'GARP-viruses only' water source; or a water source that has been granted a filtration exemption by a Drinking Water Officer.

[c] Pathogen log reduction credit assignment is based on UV equipment being fully operational and the applicable pathogen log reduction credit assignment criteria being met (see Section 7 of the Guidelines for Pathogen Log Reduction Credit Assignment).

[d] For drinking water sources that a Drinking Water Officer considers to be at risk from human fecal contamination, a 0.5-log reduction credit should be assigned because of the high level of resistance of adenovirus to UV treatment. For drinking water sources that a Drinking Water Officer does not consider to be at risk from human fecal contamination[23], a 2-log reduction credit should be assigned based on rotavirus inactivation.

[e] Refer to Table 1 for the required dose for target pathogen log inactivation.

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[23] The DWO may use their discretion to determine whether a drinking water source is at risk of fecal contamination, based on a source water assessment from the water supplier, or other studies conducted by the water supplier and provided to the DWO. Key considerations could include hydraulic connection to a known human sewage source and elevated presence of fecal indicators (i.e. *E. coli* > 20 colony forming units/100 mL).

# 11. Monitoring Parameters

Depending upon the UV control strategy used and in addition to any other sampling, analysis and recording that may be required by a Drinking Water Officer, the monitoring parameters set out in Table 5 should be tested at a minimum frequency of once every five minutes and should be recorded at a minimum frequency of once every four hours. If there is an alarm condition, the test parameters should be recorded at a minimum frequency of once every five minutes until the alarm condition has been corrected.

**Table 5: UV Equipment Monitoring Parameters**

| UV Control Strategy | Parameter Used as the Operational Set Point | Monitoring Parameters |
|---|---|---|
| UV Intensity Set Point | UV Intensity | Lamp Status<br>UV Intensity<br>Flow Rate [a] |
| Calculated Dose | Calculated or Validated Dose [b] | Lamp Status<br>UV Intensity<br>Flow Rate<br>UVT [c] |

[a] Not required for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated or certified operating conditions.

[b] The calculated dose is estimated using a dose-monitoring equation. For the calculated dose control strategy, the validated dose is equal to the calculated dose divided by the validation factor for the target pathogen to account for biases and experimental uncertainty. Refer to the U.S. EPA UVDGM for more information.

[c] UVT may not be required for some calculated dose monitoring approaches. See USEPA (2020), Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

## 11.1 Lamp Status

UV lamp status indicates whether a particular UV lamp in a reactor is on or off. Lamp status is sometimes used in the dose monitoring equation and is considered to be a validated operating condition.

## 11.2 UV Intensity

UV intensity measured as milliwatts per square centimeter of exposed area ($mW/cm^2$) describes the magnitude of UV light measured with a radiometer in bench-scale UV experiments and by a UV sensor in a reactor[24] (USEPA, 2006). Depending on the reactor design there may be multiple sensors at different points in the reactor.

UV intensity measurements are influenced by changes in lamp output due to lamp power settings, lamp aging, lamp sleeve aging, and lamp sleeve fouling. UV intensity measurements may also be influenced by the UVT of the water being treated and substances in the water which absorb or block UV transmission, such as inorganic compounds (especially iron and manganese) and natural organic matter.

### 11.3 Flow Rate

Water flow rate through a UV reactor should be monitored using a flow meter (either installed separately upstream or as part of the reactor); otherwise a device that limits the maximum flow rate into the reactor should be installed. A UV reactor should operate only at flow rates that are within its validation envelope or certified operating conditions.

For UV reactors that require flow rate monitoring, the method of flow measurement should be selected based on the flow rate variability of the treatment facility. Each UV reactor should have a dedicated flow measuring device to confirm that the reactor is operating within its specified operating range. The flow rate should be displayed locally and where required, be input directly into a control loop for the UV reactor and/or SCADA system. Minimum, maximum, and average daily flow rates should be clearly identified and recorded.

### 11.4 UV Transmittance

UV transmittance (UVT) is a measure of the percentage of incident light at a specified wavelength transmitted through a material (e.g. water) over a specified distance (pathlength normally 1 cm). UVT is typically measured at 254 nm.

## 12. Equipment Verification and Calibration

Equipment verification and calibration tests should be conducted on a regular basis to ensure that UV equipment is operating within validated or certified operating conditions and is delivering the correct UV dose for the required pathogen log inactivation.

Procedures for equipment verification and calibration tests are set out in the U.S. EPA UVDGM, DVGW W294 and ÖNORM M 5873.

### 12.1 Duty and Reference UV Sensors

Duty UV sensors are online sensors that are installed in a UV reactor to continuously measure UV intensity during reactor operation. Reference UV sensors are offline sensors that are used to evaluate

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[24] One watt = 1000 mJ/s.

and confirm duty UV sensor performance. Both types of sensors should be checked and calibrated on a regular basis to ensure that accuracy does not drift over time.

Duty UV sensors should be checked against a reference UV sensor at a minimum frequency of once every month or on a more frequent basis depending upon the recommendations of the equipment manufacturer. The calibration ratio (intensity measured with the duty UV sensor/intensity measured with the reference UV sensor) should be less than or equal to 1.2. If the calibration ratio is greater than 1.2, the duty UV sensor should be replaced with a calibrated UV sensor or a UV sensor correction factor should be applied while the problem with the duty UV sensor is being resolved.

Reference UV sensors should be factory calibrated by the sensor manufacturer at a minimum frequency of once every three years or on a more frequent basis depending upon the recommendations of the manufacturer. Reference UV sensors should be calibrated against a traceable standard such as the NIST, NPL, ÖNORM, or DVGW standards. A factory calibrated sensor should have a valid calibration certificate.

## 12.2 Flow Meters

Flow meters should be calibrated based on the frequency recommended by the flow meter equipment manufacturer or on a more frequent basis at the discretion of a Drinking Water Officer. Flow meter measurements should be within +/- 5% accuracy.

## 12.3 UVT Analyzers

UVT can be measured with a benchtop spectrophotometer or can be continuously measured by an online UVT analyzer. If the calculated dose monitoring/control strategy is used to estimate UV dose, online UVT analyzer measurements should be evaluated on at least a weekly basis by comparing online UVT measurements to UVT measurements using a calibrated benchtop spectrophotometer. The benchtop spectrophotometer should be maintained and calibrated at the frequency required by the equipment manufacturer. Calibration of UVT analyzers is necessary to determine whether a reactor is operating within its validated operating conditions. The calibration monitoring frequency can be decreased or increased based on the performance demonstrated over a one-year period. For example, the frequency could be reduced to once per month if the UVT analyzer is consistently within the allowable calibration error for more than a month during the first year of monitoring[25].

During UV reactor operation, the difference between the online UVT analyzer measurement and the UVT measured by the benchtop spectrophotometer should be less than or equal to 2%.

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[25] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

## 13. Alarm Conditions

Alarm conditions may be designated as minor, major, or critical depending upon the severity of the condition being indicated[26]:

- Minor alarms generally indicate that a UV reactor requires maintenance but that the reactor is still operating within its validated or certified operating conditions.
- Major alarms indicate that the UV reactor requires immediate attention, and that the reactor may be operating outside of its validated or certified operating conditions.
- Critical alarms typically shut down the reactor until the cause of the alarm condition can be fixed to prevent damage to the UV equipment.

**Table 6: Typical Alarm Conditions**

| Minor Alarms | Major Alarms | Critical Alarms |
|---|---|---|
| • Lamp Age<br>• UV Sensor Calibration Check [a] | • Low UV Validated Dose [b]<br>• Low UV Intensity<br>• Low UVT [c]<br>• High Flow Rate (if flow restrictor not used)<br>• Mechanical Wiper Function Failure (if applicable)<br>• Single Lamp/Ballast Failure | • Multiple Lamp/Ballast Failures<br>• Low Liquid Level and/or High Temperature [b] |

[a] May not be applicable to NSF 55 Class A certified devices, although UV sensors can be calibrated with the provision of a UV monitor (see Section 7. Reactor Certification).

[b] May not be applicable to NSF 55 Class A certified devices.

[c] Only applicable to UV reactors with online UVT monitoring (e.g. using UV intensity set point dosing strategy).

If a UV reactor malfunctions, loses power, or ceases to provide the appropriate level of disinfection, an operator should take the appropriate action at the location where the equipment is installed before water is again directed to users of the drinking water system (for systems with automatic shut-off) or before the alarm is deactivated.

For power quality alarms, if within two minutes of the alarm a further test indicates that power quality is no longer a concern, an operator need not be present at the location where the equipment is installed before water can be again directed to users of the drinking water system. The two-minute window allows a UV reactor to undergo a self-diagnostic test and to automatically reset itself.

Within 30 days following the end of a calendar month, a monthly summary report should be prepared which sets out the time, date, and duration of each major or critical UV equipment alarm that occurred

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[26] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule. Refer to Tables 4.2, 6.7 and 6.8 for alarm and monitoring schedules.

during the month, the reason for the alarm, the volume of water treated during each alarm period and the actions taken by the water supplier to correct the alarm situation. Unless otherwise notified, these summary reports should be stored onsite by the water supplier for inspection at the discretion of the DWO.

## 14. Off-Specification Water

Off-specification water[27] is produced when UV equipment is not achieving the required UV dose or log inactivation, as determined by at least one of the following criteria:

- The flowrate through the equipment is higher than the validated range;
- UVT is lower than the validated range[28];
- UV sensors are not properly calibrated; or
- UV equipment does not conform uniformly to the validated unit (i.e. the equipment does not have the same specifications as the equipment that was used for full-scale reactor validation).

Some regulatory bodies/agencies specify that in order to receive pathogen log reduction credits, at least 95% of the water delivered to the public each month should be treated by UV equipment that is operating within its validation envelope. This means that up to 5% of the water provided to drinking water users each month could be off-specification and in the absence of any other form of treatment, could potentially pose a risk to human health. This rule is intended to accommodate operational anomalies or unexpected issues, such as power outages or surges.

Production and management of off-specification water is typically addressed in terms and conditions to a water supply system's operating permit. UV equipment should be designed and selected to prevent off-specification water from entering the distribution system.

## 15. Training

Training should be provided to all personnel who are associated with UV disinfection equipment.

The training should include classroom and hands-on sessions, and should cover at least the following topics:

- An overview of how the UV equipment (as part of the water treatment facility) meets the provincial drinking water treatment objectives, including guidelines and standards that pertain to UV disinfection;
- An overview of UV disinfection principles;
- Water quality and performance monitoring;

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[27] Definition adapted from AWWA Standard F110 Ultraviolet Disinfection Systems for Drinking Water (2016).

[28] Note that flowrate through the equipment and UVT will be linked for reactors using calculated dose strategies or UV intensity variable set point strategies (i.e. units can deliver target UV dose at low UVT and low flow rates but can also deliver target UV dose at higher flow rates when UVT is higher). This validation envelope is specified in the Validation Report or Validation Certificate.

- Normal and emergency operating procedures;
- UV equipment operation and maintenance;
- UV equipment alarms and reporting requirements;
- UV equipment verification and calibration; and
- Safety requirements for operating and maintaining UV equipment, including exposure to UV light, and responding to lamp/sleeve breaks.

## 16. Equipment Start-Up and Commissioning

Before the start-up and commissioning of new UV equipment, the following documents should be submitted to the issuing official for review:

1. A commissioning plan for the new equipment including equipment calibration, functional testing, and performance testing per Section 6.1 of the U.S. EPA UVDGM;
2. A draft Operation and Maintenance Manual (O&M Manual); and
3. A training plan for all personnel who are associated with the UV disinfection facility, including operators, maintenance workers, instrumentation technicians, electricians, laboratory staff, custodial staff, engineers, and administrators (refer to Section 15 – Training).

After UV equipment installation, the following steps should be included in the reactor start-up and commissioning stages[29]:

- Prior to reactor start-up, a written certification should be obtained from the UV equipment manufacturer confirming that the UV equipment has been installed correctly.
- Upstream piping should be verified as free of sediment or debris that could damage sleeves and lamps.
- A lamp-break response procedure should be prepared, including mercury release response and cleanup procedure.
- The UV system O&M Manual standard operating protocol should be reviewed.
- Calibration checks should be performed on the instruments, sensors, and meters that will be used during equipment testing, including UVT analyzers, UV intensity sensors, and power consumption meters.
- Dry testing should be conducted with a follow-up period of wet testing. The UV equipment supplier should identify the tests that require testing with a dry reactor and those that require wet testing. Ancillary equipment should be included, such as flow meters and modulating valves.
- The UV system should be tested under all design conditions to verify that:
  - The UV dose programmed into the UV system controller matches validation with proper response to the validated range ("verification testing").
  - The UV reactor is adjusting power to maintain the target UV dose at varying flows and UVTs.

[29] Washington State Department of Health (2019). Water System Design Manual.

  - The UV system records and displays correct information for continuous monitoring and monthly reporting.
  - All alarm set points are working correctly.
  - The values reported on the UV control panel(s) match the values displayed and recorded in the SCADA system.
  - Automatic shut-off valves are working correctly (e.g. under a power failure scenario).
  - Alarms and/or automatic shut-off valves operate correctly under major and critical alarm scenarios.
  - The sleeve cleaning system is operating correctly, if included.
- The UV system should be tested for several days to verify proper performance under normal operation.

In addition to the above:

- Where required, an on-site fouling study should be conducted to inform the reactor cleaning, maintenance, and parts replacement schedule. Refer to Section 3.4.5 of the U.S. EPA UVDGM for details.

## 17. Conclusion

The information in this guideline provides provincial guidance on the reduction of pathogenic microorganisms in drinking water using UV disinfection and the design, operation, and maintenance of UV equipment for drinking water applications. Additional guidance is set out in the Design Guidelines for Drinking Water Systems in British Columbia, the Guidelines for Pathogen Log Reduction Credit Assignment and in the validation protocols and certification standard referenced in this document. In all cases, a Drinking Water Officer should be consulted when planning or considering upgrades to a drinking water supply system.

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## 19. Glossary

**Action Spectra Correction Factor (ASCF)** – a correction factor that is used to account for the greater proportional inactivation of a challenge microorganism compared to the target pathogen that results from differences in action spectra.

**Action Spectrum** – the relative efficiency of UV over a range of wavelengths at inactivating microorganisms. Each microorganism has a unique action spectrum.

**Ballast** – an electrical device that provides the proper voltage and current required to initiate and maintain the operation of a UV lamp.

**Biodosimetry** – a test procedure used to determine the reduction equivalent dose (RED) of a UV reactor by measuring the inactivation of a challenge microorganism after exposure to UV light in the reactor and comparing the results to the dose-response curve of the challenge microorganism determined by bench-scale collimated beam testing.

**Calculated Dose Approach** – a method that uses a dose-monitoring equation to determine a calculated UV dose based on the reactor's current operating conditions (flowrate, UV intensity and UVT where applicable). The calculated UV dose is divided by the reactor's Validation Factor to determine the validated UV dose. The dose-monitoring equation is normally developed during validation testing.

**Challenge Microorganism** – a non-pathogenic surrogate microorganism used in UV reactor validation testing with similar UV sensitivity and characteristics as the target pathogen.

**Collimated Beam Test** – a controlled laboratory bench-scale test that is used to determine the dose-response of a challenge microorganism. The collimated beam test apparatus uses a low-pressure UV lamp to produce collimated UV light (i.e. a beam with parallel rays and minimal dispersion) at 254 nm.

**Dose-Response** – the level of inactivation of a microorganism as a function of dose.

**EPA** – the United States Environmental Protection Agency.

**Groundwater at Low Risk of Containing Pathogens** – groundwater that is considered to be at low risk of containing pathogens as a result of a GARP assessment (i.e. no hazards were identified following a GARP Stage 1: Hazard Screening and Assessment, or the groundwater source was determined to be at low risk following a Stage 2: GARP Determination). Refer to the Guidance Document for Determining Groundwater At Risk of Containing Pathogens (GARP) when assessing the risk that groundwater may become contaminated with pathogens.

**Groundwater at Risk of Containing Pathogens (GARP)** – any groundwater supply likely to be contaminated from any source of pathogens, continuously or intermittently. Potential sources of pathogens include sewage discharge to land, leaking municipal sewage pipes (especially force mains), agricultural waste stockpiles, runoff intrusion into poorly constructed wells, and surface water.

**GARP-Virus Only** – any groundwater supply determined to be 'at risk' of containing viruses (i.e. if the DWO has reason to believe that the source is only at risk of containing viruses, and not other pathogens). This would include water supply system wells located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport or other conditions indicating possible viral contamination, therefore requiring treatment of viruses;

**Rainwater** – water collected from natural precipitation from a roof or similar structure.

**Reduction Equivalent Dose (RED)** – the UV dose derived by interpolating the log inactivation measured during full-scale reactor testing on the UV dose-response curve that was derived through collimated beam testing. May also be called the reduction equivalent fluence (REF).

**Required Dose** – the UV dose in units of $mJ/cm^2$ needed to achieve the target log inactivation for the target pathogen.

**Supervisory Control and Data Acquisition (SCADA)** – a process control system that enables drinking water treatment operators to collect data from process sensors and/or to control equipment manually or automatically. The SCADA system may be accessible in the treatment facility and/or from a remote location.

**Surface Water** – water from a source which is open to the atmosphere and includes steams, lakes, rivers, creeks, and springs.

**Target Log Inactivation** – the log inactivation that the water supplier wants to achieve using UV disinfection for the target pathogen.

**Target Pathogen** – the microorganism targeted for inactivation credit using UV disinfection.

**UV Absorbance (A)** – a measure of the amount of light that is absorbed as it passes through a material (e.g. water) over a specified distance (pathlength, normally 1 cm). UV absorbance is normally measured at 254 nm, typically on a per centimeter ($cm^{-1}$) basis.

**UV Dose** – the UV energy per unit area incident on a surface, typically reported in units of $mJ/cm^2$. The UV dose received by a waterborne microorganism in a reactor vessel accounts for the effects on UV intensity of the absorbance of the water, absorbance of the quartz sleeves, reflection and refraction of light from the water surface and reactor walls, and the germicidal effectiveness of the UV wavelengths transmitted.

**UV Equipment** – the UV reactor and related components of the UV disinfection process, including (but not limited to) UV reactor appurtenances, ballasts, and control panels.

**UV Intensity –** the power passing through a unit area perpendicular to the direction of propagation. UV intensity is used in this guidance manual to describe the magnitude of UV light measured by UV sensors in a reactor and with a radiometer in bench-scale UV experiments.

**UV Intensity Set Point Approach** – a method that uses one or more UV intensity set points to determine UV dose. The set points are based on the validation testing for the UV reactor.

**UV Light** – light with wavelengths from 200 to 400 nm.

**UV Reactor** – the vessel or chamber where exposure to UV light takes place, consisting of UV lamps, quartz sleeves, UV sensors, quartz sleeve cleaning systems, and baffles or other hydraulic controls. The UV reactor also includes additional hardware for monitoring UV dose delivery; typically comprised of (but not limited to) UV sensors and UVT monitors.

**UV Reactor Validation** – experimental testing to determine the operating conditions under which a UV reactor delivers the dose required for inactivation credit of *Cryptosporidium*, *Giardia lamblia*, and viruses.

**UV Transmittance (UVT)** – a measure of the fraction of incident light at a specified wavelength transmitted through a material (e.g. water) over a specified distance (pathlength normally 1 cm). UVT is typically measured at 254 nm unless otherwise specified (i.e. as low wavelength UVT at ~220 nm).

**Validation** – the full-scale testing of a reactor to determine its disinfection performance under all operating conditions, including flow, UVT, and lamp power.

**Validated Dose** – the UV dose in units of $mJ/cm^2$ delivered by the UV reactor as determined through validation testing. The validated dose is compared to the required dose to determine log inactivation credit.

**Validation Factor** – an uncertainty term that accounts for the bias and uncertainty associated with validation testing under the U.S. EPA UVDGM protocol.

**Validated Operating Conditions** – the operating conditions under which a UV reactor is confirmed as delivering the dose required for pathogen log reduction credit. Operating conditions should include flowrate, UV intensity as measured by a UV sensor and UV lamp status.

VILLAGE OF LIONS BAY

**BRIEFING NOTE FOR MINISTER OF MUNICIPAL AFFAIRS, HON. ANNE KANG**

**TOPIC: Water Treatment Plants for Mountain-Watershed Communities**

**BACKGROUND:**

Mountain-watershed communities, such as Lions Bay, face significant vulnerability due to the increasing risk of wildfires, which can severely compromise local water supplies. Wildfires introduce ash, sediment, and other residues into watersheds, leading to both short and long-term contamination that can impact the community's drinking water for years. The short-term issues will appear with the first rains following the event which could be within a month or so. Also, studies of fires in USA and the 2016 Ft McMurray fire have shown that the fir tree resins create a hydrophobic layer across the forest floor that starts to break down after 5-6 years contaminating the water system. More recent other fires in the Okanagan are seeing the same issues. Addressing this contamination requires advanced filtration and treatment systems that are technically complex, prohibitively expensive and therefor frequently not part of small municipalities water treatment facilities.

The financial burden of creating this infrastructure far exceeds the capacity of small communities, leaving them susceptible to prolonged water supply disruptions following a significant wildfire event. Such disruptions not only pose immediate public health risks but also undermine the long-term sustainability of these communities. Given these vulnerabilities, the Province's support in the form of external funding and long-term emergency planning is essential for ensuring the resilience and water security of communities like Lions Bay.

**REQUEST:**

The Village of Lions Bay respectfully requests that the Province of British Columbia acquire and maintain one to three skid-mounted, 500,000-gallon-per-day (GPD) water treatment plants. These portable units would be held in reserve for emergency deployment to First Nations and other small B.C. communities experiencing significant water contamination as a result of wildfires or other disasters.

**SUMMARY:**

- Wildfire Vulnerability: Mountain-watershed communities, including Lions Bay, are particularly susceptible to wildfire-related water contamination, which can compromise water quality for extended periods.
- Issues will appear within 1-2 months of the event. Procurement of a portable filtration plant will take 6-8 months.

- Financial Challenge: The infrastructure required to address such contamination is beyond the financial means of small municipalities, posing a significant burden on these communities.
- Provincial Support Request: Lions Bay requests that the Province acquire and maintain portable water treatment units to provide emergency assistance to communities impacted by water contamination. These units would ensure swift response and minimize the risk of long-term water supply disruptions.

This proactive measure will safeguard public health and support the long-term sustainability of B.C.'s mountain-watershed communities, enhancing their resilience in the face of increasing wildfire risks.