Word Count: 2989

Design Report: Rigid Pipe Attachment for Water Bottle Filling and Washing at Chestnut Residence

Contents

1 Introduction

This report recommends a rigid piping system as a solution to the difficulties associated with cleaning and filling one's water bottle in Chestnut Residence at UofT. As documented in the Design Brief (Appendix I), residents have expressed an inconvenience in washing and filling their water bottles in dorm bathrooms due to the space between the faucet and the sink being too small, in addition to the unpleasant taste of the water. This report first provides additional information on this opportunity and defines requirements and evaluation criteria based on the Design Brief, then presents the recommended design. The recommendation is then justified through comparison to alternatives, testing and verification.

2 Background

Many UofT students, including many Engineering Science students living at Chestnut, own a water bottle and use it daily. The amenities of the dorm rooms do not provide a convenient means of washing them on a regular (daily) basis. Thus, cleaning a water bottle is time-consuming due to the limited space in the sink-faucet setup, as shown in Figure 1. Filling a bottle completely is impossible, since it must be inclined to fit under the faucet. Additional concerns raised by residents also include the unpleasant taste of the tap water. The primary focus of the opportunity is on the convenience of bottle cleaning and filling, followed by the taste of water.

Figure 1. Dimensions of sink and tap configuration (left) and height comparison of faucet and bottle (right).

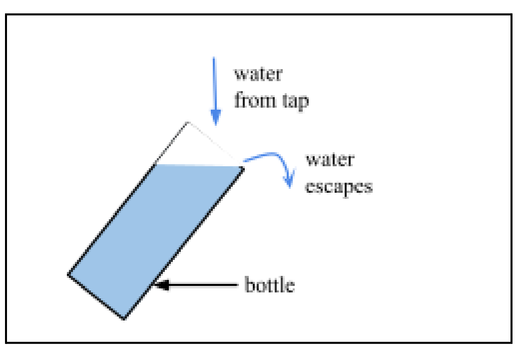

Figure 2. Diagram of a water bottle filled at a non-zero angle.

The needs, goals, and objectives (NGOs) of the opportunity are explained comprehensively in the Design Brief. To apply them, these must be reprogrammed as requirements and evaluation criteria.

3 Requirements and Evaluation Criteria

The requirements (Reqs.) developed based on the NGOs are presented in Table 1. Some requirements are direct translations of objectives, which have already been justified in the Design Brief.

Table 1. Requirements and their associated evaluation criteria.

#	Requirement	Justification	Stake-holder(s)
1	Drinking water provided by the product shall not exceed concentrations of 0.156mg/L chlorine and 125mg/L calcium.	As explained in Design Brief.	Residents
2	Water provided by the product shall contain zero detectable coliforms per 100mL.	As explained in Design Brief. Coliforms are indicator bacteria that signal contamination in drinking water [2].	Residents, UofT S&E
3	The system shall take at most 10 seconds for each of setup, switching between functions, and dismantling after use.	As explained in Design Brief. Moreover, the time it takes to fill a water bottle using campus water fountains is approximately 20 seconds. Setup and dismantling should take less than this time, so we will limit setup and dismantling times to 10 seconds each.	Residents
4	The system shall require zero extra tools to set up to be ready to fill and clean a water bottle.	As explained in Design Brief.	Residents
5	The system shall require at most a pushing/pulling force of 23N, and a torque of 680mN$\cdot$m applied by hands.	As explained in Design Brief.	Residents
6	Splashing, if any, shall be contained to a radius of less than 15.5cm.	As explained in Design Brief.	Residents, Cleaning staff

7	Water shall be supplied at a flow rate of at least 2.7L/min.	This is the measured maximum flow rate in Chestnut Residence. Since faucet-attachment designs cannot exceed this flow rate, it is set as a minimum limit, in order to ensure designs don't slow it further.	Residents
8	The system shall allow residents to completely fill cylindrical water bottles with dimensions at least up to 30cm in height and 11cm in diameter.	As explained in Design Brief.	Residents
9	The system shall be able to accommodate water temperature in the range 15-49ºC	As explained in Design Brief.	Residents, UofT S&E
10	The system shall function properly for at least 1200 filling and washing cycles without replacement parts or maintenance.	As explained in Design Brief.	Residents
11	The system shall expose the user to temperatures no greater than 49°C.	49°C is the temperature limit for prolonged contact with a metal surface without causing burns, as per MIL-STD-1472H [3]. Metal surfaces have the most restrictive temperature limits among the materials included in the standard. 49°C is also the maximum tap water temperature recommended by the Government of Canada [4].	Residents, UofT S&E
12	The system shall provide water at a pressure of no greater than 415kPa.	Exposure to high-pressure water jets can cause injuries. CSA C22.2 NO. 167:23, recommends that household dishwashers be tested with a water pressure of up to 415kPa [5]. Dishwashers are common and safe household appliances, and thus, 415 kPa can be considered a safe pressure.	Residents
13	The system shall not expose users to harmful effective Actinic UV irradiance to $3mJ/cm^2$ over 8 hours.	UV exposure limits are enforced in Ontario under Section 25(2)(h) of the OHSA, based on ACGIH Threshold Limit Values, limiting a Max Effective Actinic of $3mJ/cm^2$ over 8 hours [6].	Residents, UofT S&E

14	The system shall occupy no more than an area of 400cm^2 of counter space when not in use.	Counter space in Chestnut's ensuite bathrooms is limited, and obstructions make it difficult to clean the counter. Common objects, such as hairdryers, occupy ~400cm^2, so this can be considered an acceptable amount of space for the design to occupy.	Residents, Cleaning Staff
15	The system shall require replacement of consumable components no more than 6 times per year.	A common product used by Chestnut residents is the Brita filter system, which requires a filter to be changed approximately 6 times per year [7].	Residents

The evaluation criteria (ECs) are presented in Table 2.

Table 2. Evaluation Criteria.

EC#	Evaluation Criterion	Justification
1	The shorter the time (in seconds) needed to set up, switch functions, and dismantle, the better.	Same as Req. 3.
2	The smaller the splash radius (in cm), the better.	Same as Req. 6
3	The larger the maximum height and width of the water bottle (in cm) that can be accommodated, the better.	Same as Req. 8
4	The smaller the area of counter space occupied (in cm^2) when not in use, the better.	Same as Req. 14
5	The lower the frequency of consumable component replacement (in # components per year), the better.	Same as Req. 15

3.1 Selection of Key Requirements and Evaluation Criteria

A pairwise comparison was performed on the fifteen requirements to determine which are most relevant to test. The results are in Appendix B (Table 7). The following are the requirements that were chosen to be verified:

- **Requirement 4. The system shall require no additional tools to set up to be ready to fill and clean a water bottle.** This requirement is vital to ensure the convenience of the overall design, which is prioritized over taste. Additionally, safety was determined to be a minor factor, since it is difficult to make an unsafe water filling station, which places this requirement at a higher value than safety ones.

- **Requirement 6. Splashing, if any, shall be contained to a radius of less than 15.5cm.** If the design forces people to spend more time cleaning up the faucet or the surroundings, it becomes more time-consuming and misses the whole point of making people clean or fill the water bottle more quickly.

- **Requirement 7. Water shall be supplied at a flow rate of at least 2.7L/min.** This flow rate is necessary to fill a bottle in a sufficiently short time. This relates to convenience, which is a central part of the opportunity.

- **Requirement 8. The system shall allow residents to completely fill cylindrical water bottles with dimensions at least up to 30cm in height and 11cm in diameter.** The Splartz focuses on the sink setup, which is unable to accommodate an appropriate range of water bottle sizes. This requirement ensures that the proposed design solves this issue, hence it is at the forefront of consideration.

- **Requirement 13. The system shall not expose users to harmful ultraviolet radiation.** Of all the safety requirements, UV safety was deemed to be the most important since it can be quite harmful even in small doses [8]. The other safety concerns are also much simpler to achieve than UV safety, and hence are much less of a concern than the latter. Thus, it is vital to consider UV safety when analyzing designs.

4 Recommended Design: Faucet-Mounted Rigid Pipe Attachment

The recommended solution to the previously outlined issue is the Rigid Pipe Faucet Attachment. This design features a rigid piping system that attaches onto the faucet using a quick release lever, and redirects the water flow upwards. This allows for easy filling and cleaning of nearly any water bottle. The dimensions of the piping are calculated to accommodate the largest water bottles typically used by students [9-11], and the diameter of the pipe is determined such that the flow rate of water is unhindered. This meets requirements 7 and 8, as previously outlined. Additionally, a charcoal water filter [12] is inserted into the base of the piping, to provide better-tasting water, which is optimized for requirements 1 and 2.

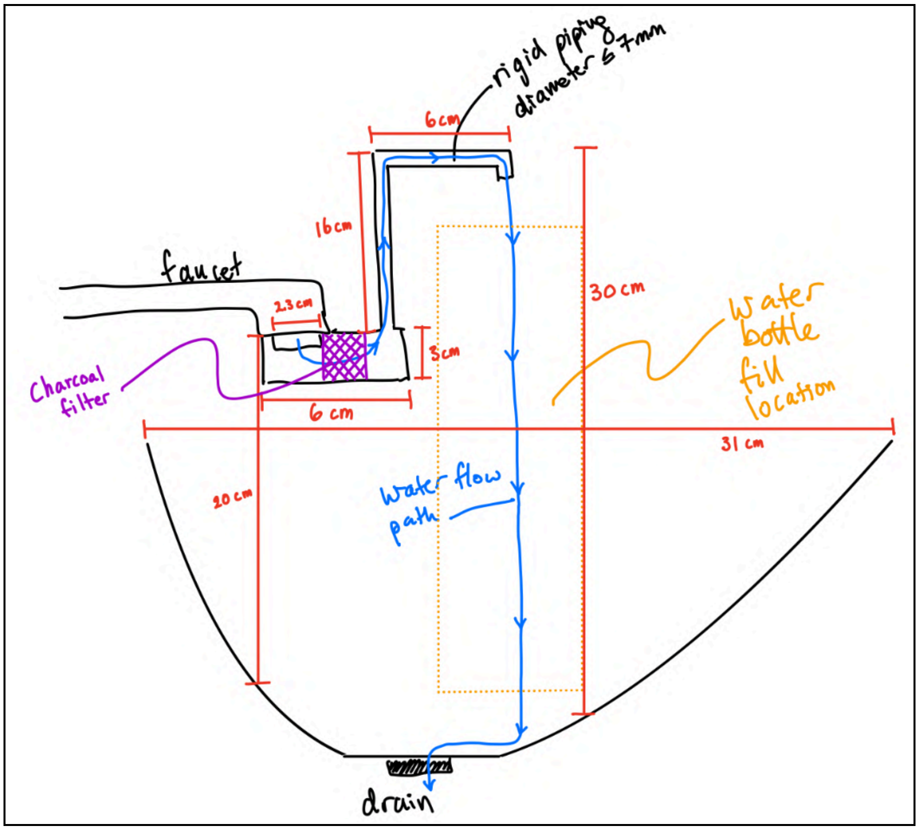

Figure 3. Drawing of the faucet-mounted rigid pipe attachment.

5 Overview of Alternative Design Concepts Considered

This section outlines three other designs that were compared to the eventual recommended design. They all solve the same set of issues in different ways, which is why they all provide valuable insight into the key attributes a functional design should have.

The alternate solutions were found using various diverging tools. 'Challenging Assumptions' which is shown in Figure 8 in Appendix F was used primarily to find new ways to wash bottles, such as with UV light, as well as solutions other than a faucet attachment, like the reservoir. A Morph Chart (Appendix F) was also used for diverging, since the opportunity lends itself well to being decomposed into functions.

5.1 Faucet-Mounted Fountain Attachment

This design took inspiration from common water fountains, proposing that the water stream be redirected upwards in an arc. The peak of the arc has to accommodate the required water bottle size, and the flow rate has to remain unchanged. Referring to Figure 4, the design attaches to the faucet using a quick-release lever, which is optimized for requirement 3. The water is redirected upwards in a trajectory that accommodates the required water bottle size, at a faucet flow rate of 2.7L/min. Additionally, the design features a charcoal filter that satisfies requirements 1 and 2. Calculations for the dimensions of this design can be seen in Appendix H.

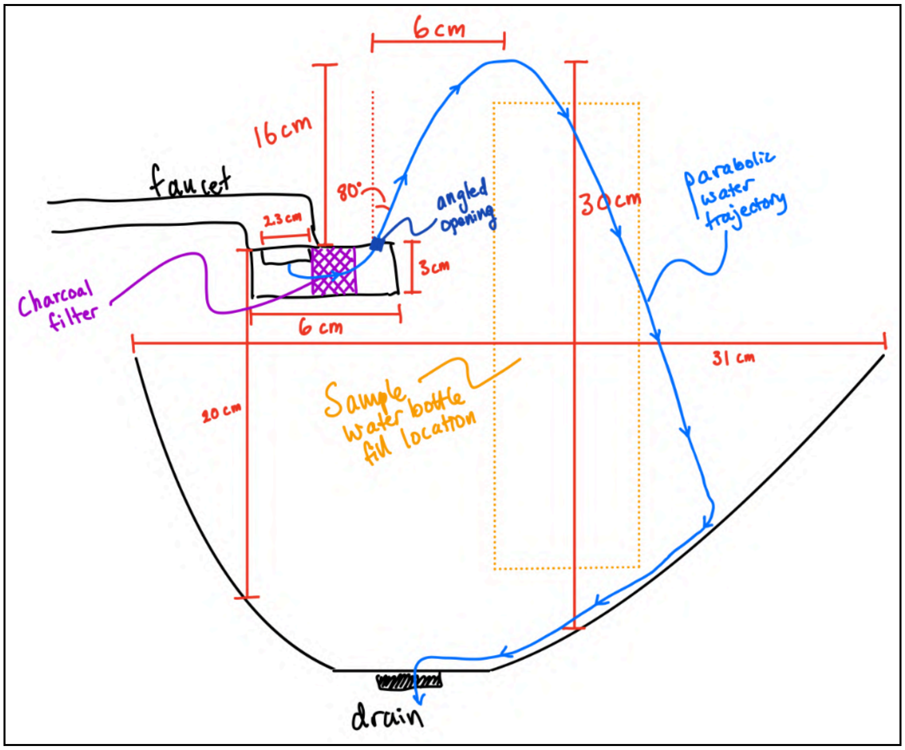

Figure 4. Drawing of the faucet-mounted fountain attachment.

5.2 Reservoir with UV Disinfection

This design comprises a reservoir, filtration system, and UV disinfection system. The reservoir is filled through a hole at the top using a hose, then passes through a filter into a UV disinfection chamber, allowing the user to dispense the water for drinking. There is a compartment on the left side that allows the user to place their water bottle in an isolated chamber for UV disinfection. To ensure user safety and compliance with Ontario's OHSA regulations, the chamber is fully enclosed with stainless steel to prevent UV leakage above the ACGIH limit of 3mJ/cm^2. This isolated chamber accommodates the range of water bottle sizes outlined by requirement 8 [9-11].

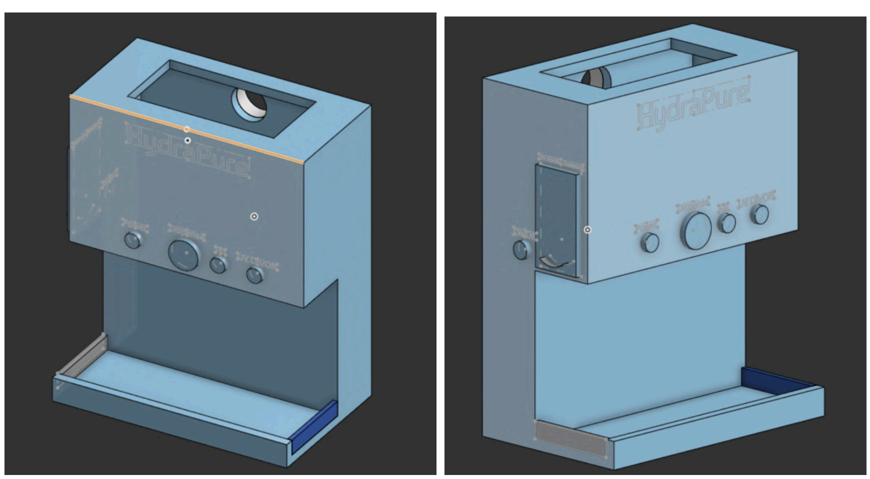

Figure 5. 3D CAD representation of the UV Disinfection prototype modelled in OnShape [13]. A portion of the reservoir's top has been removed to reveal the inner compartments.

5.3 Reference Design: Faucet-Mounted Hose and Sprayer

This design features a flexible hose attachment for the faucet, directing the water to a handheld spraying device, as shown in Figure 6.

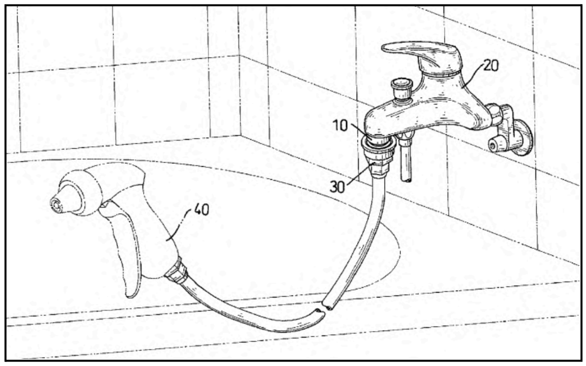

Figure 6. Drawing of a faucet hose connector [14]. The connection (30) is threaded and can be screwed to a faucet with threads and directs water into a tube, which is in turn connected to a spraying device at the distal end (40) [14].

This solution allows users to bypass the vertical distance restrictions between the Chestnut ensuite bathroom tap and sink basin. The spraying mechanism allows the user to adjust the pressure of the water delivered to the bottle accordingly by changing the force applied to the handle. This provides flexibility in the use of the design, allowing users to effectively switch between filling and cleaning functions immediately. To filter, it is possible to use an existing filtering jug similar to a Brita filter [7].

6 Key Design Decisions and Comparisons of Designs

This section presents the key design decisions that led to the recommended design, resulting from comparisons between alternative designs. Justifications of design choices refer heavily to data from tests and research, summarized in a measurement matrix. Thus, the measurement matrix will be presented first, followed by a Pugh Chart and justifications of design decisions.

6.1 Data Collection and Measurement Matrix

Multiple procedures were performed to measure values for the measurement matrix following evaluation criteria, shown in Table 3.

Table 3. Measurement matrix with prioritized requirements and evaluation criteria.

	Faucet-Mounted Rigid Pipe Attachment	**Faucet- Mounted Fountain Attachment**	**Reservoir with UV Disinfection**	**Faucet-Mounted Hose and Sprayer**
Req. 3 / EC.1: Setup time	1.0s	1.0s	2-5mins	2.5s
EC.4: Counter space occupied when not in use	$120cm^2$ (12x10)	$18cm^2$ (6x3)	$400cm^2$ (20x20)	$180cm^2$
Req. 6 / EC.2: Splash Radius (cm)	<15.5	<15.5	0	<15.5
Req 7: Flow Rate (L/min)	2.7	2.7	2.7	2.7
Req. 8: Water Bottle Height Accommodable (cm)	≤30	≤30	≤30	≥30
Req. 13: User Exposure to UV Radiation	None	None	None	None
EC5: Frequency of Component Replacement (components/year)	6	6	6	6

- First, the setup times (Req. 3) were measured experimentally by timing different attachment methods as per Appendix A. The reservoir setup time estimate is 2-5 minutes, as this is generally the time it takes UV lamp reference designs to warm up before flow begins [15].
- The counter space (EC.4) occupied by each design is calculated using the dimensions of each design, as described in Appendix E.
- Splash radius (Req. 6) was found by measuring distance of splash marks on a paper-towel setup around the splash location, as per the procedure described in Appendix A (with video).
- Flow rate (Req. 7) of the faucet was calculated by timing the filling of a 250mL container as in Appendix A (with video).
- All but the last design are created for a water bottle size limited at 30cm (Req. 8). The hose attachment is long and flexible, hence accommodates larger sizes.

- The only design incorporating UV disinfection is the UV reservoir (Req. 13). In this design, the chambers are enclosed with stainless steel to prevent the user from any exposure to UV radiation [17, 18], so UV exposure for this design is also considered to be "none".
- Finally, the charcoal filter (present in every design) is consumable and needs to be replaced 6 times a year [7], according to data on reference filter designs (EC. 5).

Tests involving verification of physical prototypes are documented in the following video:
https://drive.google.com/file/d/1c0CxTIkPuguicJd9abFlZZrZ7Yqt-3Ne/view?usp=sharing

6.2 Pugh Charts

Using data from the measurement matrix, Pugh Charts were created to further compare designs. Additional Pugh Charts are in Appendix C.

Table 4. Pugh Chart with Faucet-Mounted Rigid Pipe Attachment as Reference.

Metric (EC)	***Reference:*** **Faucet-Mounted Rigid Pipe Attachment**	**Faucet-Mounted Fountain Attachment**	**Reservoir with UV Disinfection**	**Faucet-Mounted Hose and Sprayer**
EC.1: Setup time	Same	Same	Worse	Worse
EC.2: Splash Radius (cm)	Same	Same	Better	Same
EC.3: Water Bottle Size Accommodable	Same	Same	Same	Better
EC.4: The Less Counter Space Required When not in Use, the Better	Same	Better	Worse	Worse
EC.5: Frequency of Component Replacement	Same	Same	Same	Same
Total # Better and Worse	NA	1 Better	1 Better 3 Worse	1 Better 2 Worse

6.3 Key Design Decisions Leading to Rigid Pipe Attachment Recommendation

A quick-release connection was chosen over a threaded connection. Using the measurement matrix (Table 3), it was determined that the hose design has a longer setup time. Since the hose uses a threaded connection, and the others use a quick-release lever, the final design should use a quick-release lever.

Next, a rigid pipe was chosen over a fountain. In Table 4, the fountain design performs better than the rigid piping on counter-space use. Thus it could be concluded that it should be the recommendation. However, the fountain is much more susceptible to water pressure variation, which could result in spillage outside the sink, or insufficient height to fill a water bottle. Since this affects the convenience in two separate aspects, filling and cleanup, this is a more significant issue than storage space.

Then, a rigid pipe was also chosen over a hose. Although the extended hose attachment can accommodate larger bottle sizes, it must always be held to ensure accurate water flow. This means that only one hand is available to clean. Given that all designs can already accommodate the size requirement set by the objectives in the Design Brief, the extra range is unworthy of the inconvenience.

Finally, handwashing with soap was chosen over UV light disinfection. Although the UV reservoir creates less splashing, given cleaning doesn't use water, it requires significantly more setup time since the UV needs to be prepped for use. Since the warm-up time is much larger than the rest, it is deemed a bigger inconvenience than slightly more splashing. Additionally, 15.5 cm falls within the bounds of the sink, hence is not an issue. Therefore, the UV design is most inconvenient.

7 Conclusion

Overall, we bathed in the fountain of possibilities of bottle filling and washing. As explained in previous sections, the Faucet-Mounted Rigid Pipe Attachment's simplicity allows it to perform well in all requirements and evaluation criteria, while not suffering from significant drawbacks that other designs face. Thus, it was determined to be the best design to address the bottle filling and washing opportunity at Chestnut.

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Appendix A. Testing Procedures

To validate the recommended design and compare it with the alternatives, tests were conducted to assess how well they meet the key requirements identified in Section 3: Setup Time (Req 3), Splash Radius (Req 6), and Flow Rate (Req 7).

Tests involving verification of physical prototypes are documented in the following video:
https://drive.google.com/file/d/1c0CxTIkPuguicJd9abFlZZrZ7Yqt-3Ne/view?usp=sharing

Test 1: Setup and Dismantling Time

A stopwatch was used to record the time required to complete the setup and dismantle each design concept.

1. Direct attachments:
    a. The prototype began sitting on the sink counter.
    b. The stopwatch was started when the user began securing the prototype to the faucet.
    c. After fully securing it, the attachment was immediately removed. The stopwatch was stopped the moment that the design was fully removed from the faucet.

Test 2: Splash Radius Proxy Test

This test procedure is adapted from the method used in a study on splashing in medical cleaning settings [19]. This is documented in the video.

1. The paper towel was put around the sink to play the role of detection paper.
2. The location where the water is poured was being marked in the sink
3. Water was poured from a specific height from the location we marked according to the design's dimensions.
4. The farthest position of the watermark was found on the paper towel.
5. The distance from the farthest position to the pouring location was measured. This distance is used to represent the farthest splashing radius.

Test 3: Flow Rate

This test procedure is adapted from a government regulation on water consumption [21]. This is documented in the video.

1. Obtained a standard-sized container of known volume
2. Went to 4th floor, where the flow rate is highest [20], and timed the filling of said container using faucet
3. Calculated flow rate from this in L/min.

Appendix B. Pairwise Comparison Matrices

Table 5. Pairwise Comparison for Design Concepts

	Faucet-Mounted Rigid Pipe Attachment	Faucet-Mounted Fountain Attachment	Reservoir with UV Disinfection	Faucet-Mounted Hose and Sprayer	Sum
Faucet-Mounted Rigid Pipe Attachment	X	1	1	1	**3**
Faucet-Mounted Fountain Attachment	0	X	1	1	2
Reservoir with UV Disinfection	0	0	X	0	0
Faucet-Mounted Hose and Sprayer	0	0	1	X	1

Table 6. Pairwise Comparison of Evaluation Criteria

	EC1. Time to set up	EC2. Splash Radius	EC3. Size Accommo-dating	EC4. Counter Space	EC5. Component Replacement	Sum
EC1. Time to set up	X	1	0	1	1	3
EC2. Splash Radius	0	X	0	1	1	2
EC3. Size Accommodating	1	1	X	1	1	4
EC4. Counter Space	0	0	0	X	1	1
EC5. Component Replacement	0	0	0	0	X	0

Table 7. Pairwise Comparison of Requirements (requirements and their corresponding number are listed below the table).

Req. #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Sum**
1		0	0	0	0	0	0	0	1	0	1	1	0	0	1	4
2	1		0	0	0	0	0	0	1	0	1	1	0	0	1	5
3	1	1		1	0	1	1	0	1	1	1	1	0	0	1	10
4	1	1	0		1	0	0	0	1	1	1	1	0	1	1	9
5	1	1	1	0		0	0	0	0	0	0	1	0	0	0	4
6	1	1	0	1	1		1	0	1	1	1	1	0	1	1	11
7	1	1	0	1	1	0		0	1	1	1	1	0	1	1	10
8	1	1	1	1	1	1	1		1	1	1	1	0	1	1	13
9	0	0	0	0	1	0	0	0		1	0	0	0	0	1	3
10	1	1	0	0	1	0	0	0	0		1	1	0	0	0	5
11	0	0	0	0	1	0	0	0	1	0		1	0	0	1	4
12	0	0	0	0	0	0	0	0	1	0	0		0	0	1	2
13	1	1	1	1	1	1	1	1	1	1	1	1		1	1	14
14	1	1	1	0	1	0	0	0	1	1	1	1	0		1	9
15	0	0	0	0	1	0	0	0	0	1	0	0	0	0		2

Requirement numbers:

1. Drinking water provided by the product shall not exceed concentrations of 0.156 mg/L chlorine and 125 mg/L calcium.

2. Water provided by the product shall contain zero detectable coliforms per 100 mL.

3. The system shall require less than 10 seconds of setup, 10 seconds to switch between filling and washing functions, and 10 seconds to dismantle to return to regular use of the room.

4. The system shall require zero tools to set up to be ready to fill and clean a water bottle, besides the design itself.

5. The system shall require at most a pushing/pulling force of 23 N, and a torque of 680 mN · m applied by hands.
6. Splashing, if any, shall be contained to a radius of less than 15.5 cm.
7. Water shall be supplied at a flow rate of at least 2.7 L/min.
8. The system shall allow residents to completely fill cylindrical water bottles with dimensions at least up to 30 cm in height and 11 cm in diameter.
9. The system shall be able to accommodate water temperature in the range 15-49 ºC.
10. The system shall function properly for at least 1200 filling and washing cycles without replacement parts or maintenance.
11. The system shall expose the user to temperatures no greater than 49°C.
12. The system shall provide water at a pressure of no greater than 415 kPa.
13. The system shall not expose users to harmful effective Actinic UV irradiance to 3 mJ/cm2 over 8 hours.
14. The system shall occupy no more than an area of 400 cm2 of counter space when not in use.
15. The system shall require replacement of consumable components no more than 6 times per year.

Appendix C. Additional Pugh Charts

Table 8. Pugh Chart with Faucet-Mounted Fountain Attachment as Reference.

Metric (EC)	**Faucet-Mounted Rigid Pipe Attachment**	***Reference:*** **Faucet-Mounted Fountain Attachment**	**Reservoir with UV Disinfection**	**Faucet-Mounted Hose and Sprayer**
EC.1: Setup time	Same	Same	Worse	Worse
EC.2: Splash Radius (cm)	Same	Same	Better	Same
EC.3: Water Bottle Size Accommodable	Same	Same	Same	Better
EC.4: The Less Counter Space Required When not in Use, the Better	Worse	Same	Worse	Worse
EC.5: Frequency of Component Replacement	Same	Same	Same	Same
Total # Better and Worse	1 Worse	NA	1 Better 3 Worse	1 Better 2 Worse

Table 9. Pugh Chart with Reservoir with UV Disinfection as Reference.

Metric (EC)	**Faucet-Mounted Rigid Pipe Attachment**	**Faucet-Mounted Fountain Attachment**	***Reference:* Reservoir with UV Disinfection**	**Faucet-Mounted Hose and Sprayer**
EC.1: Setup time	Better	Better	Same	Better
EC.2: Splash Radius (cm)	Worse	Worse	Same	Worse
EC.3: Water Bottle Size Accommodable	Same	Same	Same	Better
EC.4: The Less Counter Space Required When not in Use, the Better	Better	Better	Same	Better
EC.5: Frequency of Component Replacement	Better	Better	Same	Better
Total # Better and Worse	3 Better 1 Worse	3 Better 1 Worse	NA	4 Better 1 Worse

Table 10. Pugh Chart with Faucet-Mounted Hose and Sprayer as Reference.

Metric (EC)	**Faucet-Mounted Rigid Pipe Attachment**	**Faucet-Mounted Fountain Attachment**	**Reservoir with UV Disinfection**	***Reference:*** **Faucet-Mounted Hose and Sprayer**
EC.1: Setup time	Better	Better	Worse	Same
EC.2: Splash Radius (cm)	Same	Same	Better	Same
EC.3: Water Bottle Size Accommodable	Worse	Worse	Worse	Same
EC.4: The Less Counter Space Required When not in Use, the Better	Better	Better	Worse	Same
EC.5: Frequency of Component Replacement	Same	Same	Same	Same
Total # Better and Worse	2 Better 1 Worse	2 Better 1 Worse	1 Better 4 Worse	NA

Appendix D. Calculation of Pipe/Hose Diameter

Known or set values:

$Q = desired\ flow\ rate = 2.7\ L/min = 4.57 \times 10^{-5}\ m^3 \cdot s^{-1}$ (as measured from tap).

$g = gravitational\ acceleration = 9.81\ m \cdot s^{-2}$.

$h = maximum\ height\ above\ faucet\ reached\ by\ water = 0.16\ m$.

The required diameter of pipe required for the water to be pushed through the vertical section of the pipe/hose can be calculated as follows, by balancing the weight of water pushing back on the faucet F_g to the force of water exiting the faucet F_w:

$$F_g = F_w\ .$$

Since $F_w = \frac{dp}{dt} = \frac{dm}{dt}v = \rho Q \cdot \frac{Q}{A} = \frac{\rho Q^2}{A}$ and $F_g = \rho V g = \rho A h g$, we get the equation

$$\rho A h g = \frac{\rho Q^2}{A} \Rightarrow A = \sqrt{\frac{Q^2}{hg}} \Rightarrow \frac{\pi d^2}{4} = \sqrt{\frac{Q^2}{hg}}$$

$$\Rightarrow d = \sqrt{\frac{4}{\pi}\sqrt{\frac{Q^2}{hg}}} = \sqrt{\frac{4}{\pi}\sqrt{\frac{\left(4.57\times10^{-5}\ m^3\cdot s^{-1}\right)^2}{(0.16\ m)\left(9.81\ m\cdot s^{-2}\right)}}} = 6.82 \times 10^{-3}\ m \approx 7\ mm.$$

Thus, the rigid pipe design and flexible hose design would have a diameter of 7 mm.

Appendix E. Calculation of Area Occupied by Hose Attachment When not in Use

Known or set values:

$$L = total\ length\ of\ hose = 18.8 + 10 + 18.8 = 47.6\ cm.$$

The value of L was determined by estimating the lengths of three sections of the hose: an 18.8 cm segment near the faucet that rediverts the water upward, a 10 cm segment that carries the water upward, and a final 18.8 cm segment at the end of the hose that rediverts the water in the direction of the mouth of the bottle.

If the hose is looped into a circle for storage, the area occupied by that circle can be calculated as follows:

$$C = L \Rightarrow 2\pi R = L \Rightarrow R = \frac{L}{2\pi}.$$

And the area of a circle is $A = \pi R^2$, therefore

$$A = \pi\left(\frac{L}{2\pi}\right)^2 = \pi\left(\frac{47.6\ cm}{2\pi}\right)^2 = 180\ cm^2.$$

Appendix F. Diverging Tools

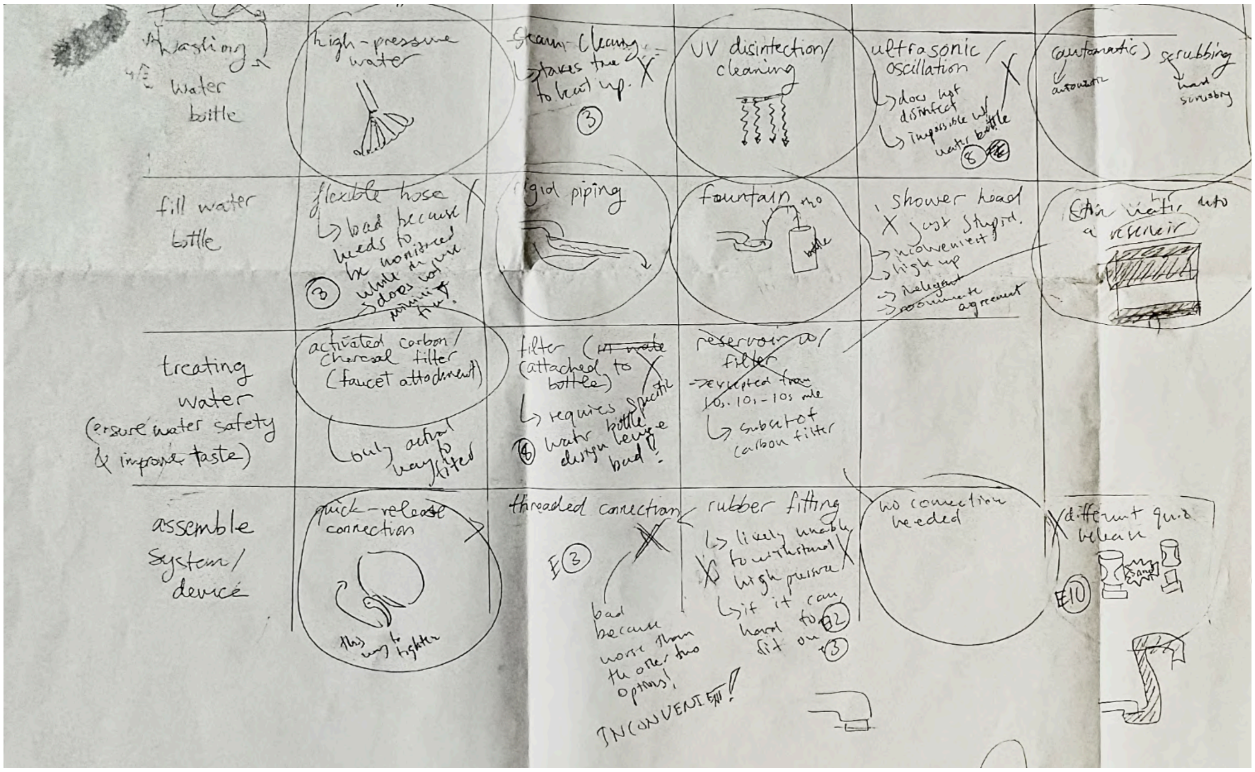


Figure 7. Morph Chart

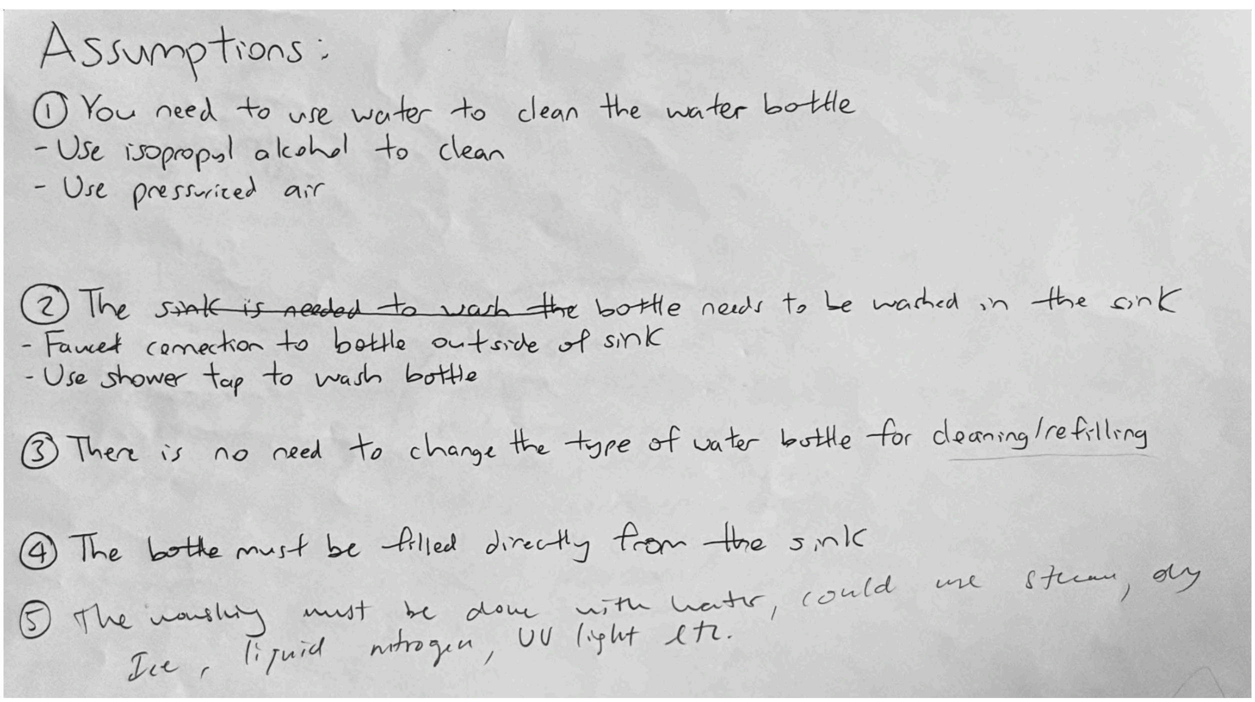


Figure 8. Challenging Assumptions

Appendix G. Estimating UV Reservoir Lamp Use

According to the University of Toronto Sessional Dates for Engineering Students [22], classes run from September 2, 2025, to April 30, 2026, for the 2025-2026 school year. A week before and after these dates, inclusive, will be considered for moving in and out of residence. We chose to use the Engineering faculty calendar as most Chestnut Residence students are in this faculty [23].

Using this information, the maximum number of days a student stays in residence is 255 days. It is estimated that an individual at Chestnut Residence will have the UV lamp on for at most 1 hour per day. Therefore, the estimated maximum time a student at Chestnut Residence would use the UV lamp is:

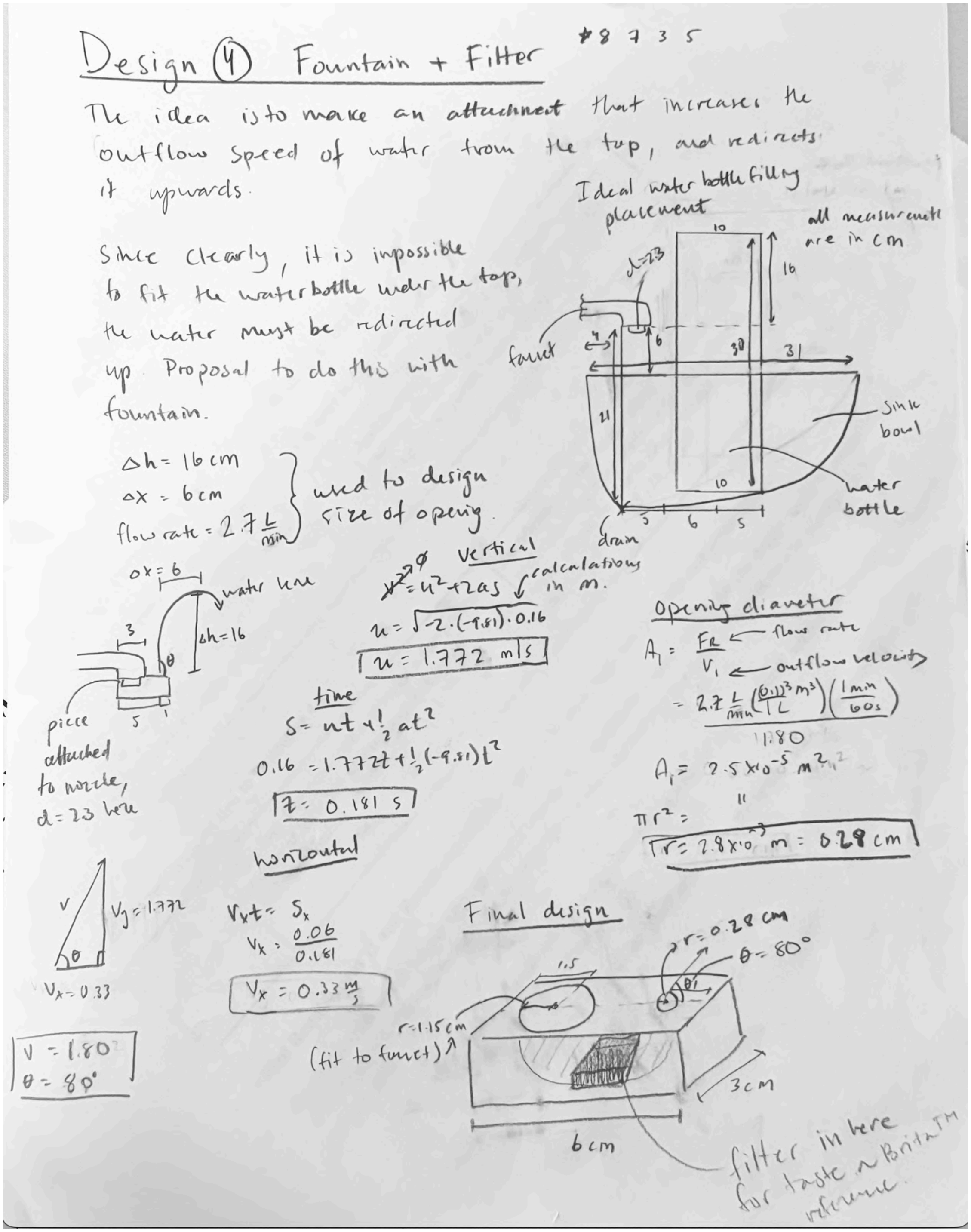
$$255\ hours/year$$

Multiple this by a factor of four to account for all years of undergraduate living in residence:

$$255 \times 4 = 1020\ hours$$

As seen in these calculations, this value is significantly lower than 9000 hours, the number of hours where the effective UV output begins to degrade [16], supporting that with proper use, users will never need to replace the UV reservoir's lamp.

Appendix H. Calculations for Faucet-Mounted Fountain Attachment


Design (4) Fountain + Filter #8 7 3 5

The idea is to make an attachment that increases the outflow speed of water from the tap, and redirects it upwards.

Since clearly, it is impossible to fit the waterbottle under the tap, the water must be redirected up. Proposal to do this with fountain.

$\Delta h = 16$ cm
$\Delta x = 6$ cm
flow rate $= 2.7 \frac{L}{min}$
} used to design size of opening.

Vertical (calculations in m.)

$v^2 = u^2 + 2as$

$u = \sqrt{-2 \cdot (-9.81) \cdot 0.16}$

$u = 1.772$ m/s

time

$s = ut + \frac{1}{2}at^2$

$0.16 = 1.772t + \frac{1}{2}(-9.81)t^2$

$t = 0.181$ s

horizontal

$V_x t = S_x$

$V_x = \frac{0.06}{0.181}$

$V_x = 0.33 \frac{m}{s}$

$V = 1.80$
$\theta = 80°$

Opening diameter

$A_1 = \frac{F_R}{V_1}$ ← flow rate, ← outflow velocity

$= \frac{2.7 \frac{L}{min} \left(\frac{(0.1)^3 m^3}{1 L}\right)\left(\frac{1 min}{60 s}\right)}{1.80}$

$A_1 = 2.5 \times 10^{-5}$ m²

$\pi r^2 =$ ''

$r = 2.8 \times 10^{-3}$ m $= 0.28$ cm

Final design

Appendix I. Design Brief

Word Count: 1724

Design Brief for Better Water Bottle Washing and Filling at Chestnut Residence

1 Introduction

This design brief provides explanations and guidance for improving means of filling and washing water bottles for students living in Chestnut Residence dorms (Chestnut) at the University of Toronto (UofT). Chestnut accommodates almost 1150 students [2]. Some residents have expressed dissatisfaction with the inconvenience of washing and filling their water bottles in dorm bathrooms due to the space between the faucet and the sink being too small to easily accommodate their water bottles, as well as the unpleasant taste and odour of the water. This report explains the opportunity to address this inconvenience, analyzes stakeholders, examines reference designs, and sets out the need, goals and objectives (NGOs) for this opportunity.

2 Definition and Justification of the Opportunity

Many UofT students, including many Engineering Science (EngSci) students living at Chestnut, own a water bottle and use it daily. These bottles need to be filled and washed regularly. The amenities of the dorm rooms do not provide a convenient and pleasant means of filling and washing residents' water bottles. Thus, an improved system would be valuable.

An interview conducted with an anonymous UofT EngSci student living at Chestnut considered it more time-consuming to clean their bottle due to the limited space in the sink below the faucet (see full transcript in Appendix 9.2). The student was also unable to completely fill their water bottle for the same reason. Moreover, the student mentioned how they avoid filling their bottle in their room altogether due to the unpleasant taste of the tap water. The student also agreed that they would prefer to fill their water bottle in their room if it were more convenient and pleasant.

These observations are consistent with the following information. The three most common water bottle brands sold on Amazon [7] are Owala, Stanley, and Yeti (dimensions of bottles sold provided in Appendix 9.1). The largest among them has a height of ~30 cm [10]. Thus, larger bottles do not fit into the sink, where the difference between the tap and the bowl is 20 cm, as shown in Figure 1. The bottle must be tilted at an angle to align its opening with the mouth of the faucet. Consequently, it is impossible to fill the bottle completely, as shown in Figure 2.

Figure 1: Dimensions of sink and tap configuration (left) and height comparison of faucet and water bottle (right).

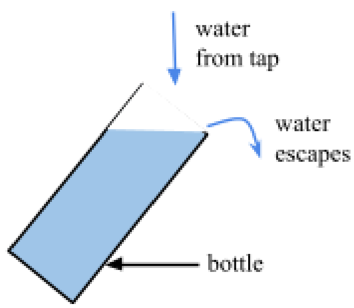


Figure 2: Diagram of a water bottle filled at a non-zero angle. A considerable volume of the bottle is unfilled.

Unpleasant tastes like those mentioned by the interviewed student can be caused in part by excess chlorine and calcium concentrations, as well as certain bacteria in the water [14].

3 Stakeholder Analysis

This section categorizes stakeholders and identifies their interests and influence.

3.1 Primary Stakeholders

- UofT students living at Chestnut Residence who use water bottles. The need and goals of this opportunity will mainly be based on the interests of residents.
- This design team will set out the NGOs that influence future solutions. The responding team will make design choices for a future solution.

3.2 Secondary Stakeholders

- UofT Spaces and Experiences (S&E) (the residence administration) may affect future solutions through safety regulations.

3.3 Tertiary Stakeholders

- People in other university residences or in some apartments may also benefit from the future design. Their interests may or may not align with those of Chestnut residents (scope is limited to Chestnut).

4 Examination of Reference Designs

This section points out some more aspects relating to stakeholder expectations, based on observations from reference designs.

4.1 Faucet Hose Connector: Addressing Spatial Limitations

The design of the connector shown in Figure 3 supports the stakeholder expectation of addressing spatial limitations. This connector is designed to supply a stream of water to a location other than the area in the sink just below a faucet [19]. The connector thereby bypasses the spatial limitations of the water supply. This responds to the residents' expectation of bypassing the height limitation of bathroom faucets.

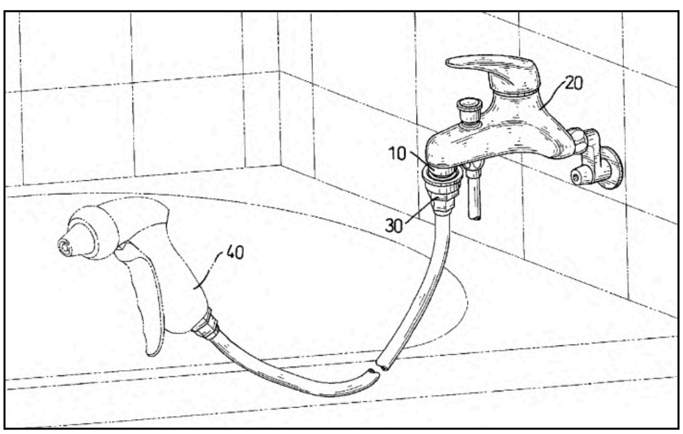


Figure 3. Drawing of a faucet hose connector [19]. The proximal end (30) is threaded and can be screwed to a faucet with threads and directs water into a tube, which is in turn connected to a spraying device at the distal end (40) [19].

This design also highlights the importance of usability. Using this connector to clean a bottle would require one hand to hold and direct the water jet while the other holds the bottle. This would be inconvenient if the resident needs to alternate between scrubbing/soaping and rinsing in quick succession. The threaded end used to attach the connector to the faucet would also be time-consuming to use if frequent attachment/detachment is required. This design is also a potential harbourer for bacteria due to its long shape and inability to be cleaned effectively.

4.2 Atomizer Nozzle: Maintaining Cleanliness

Although the nozzle design in Figure 4 alone would not allow residents to fill their water bottles, the design brings up cleanliness as an aspect of convenience. The nozzle can produce an atomized flow of water consisting of many tiny droplets, which reduces splashing [20]. Otherwise, more splashing would require inconvenient wiping/drying after each use.

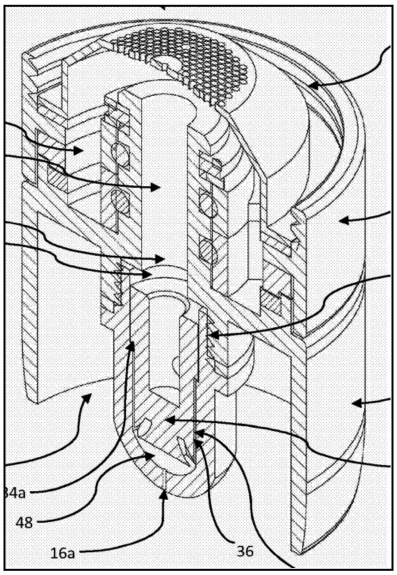


Figure 4. Drawing of the atomizer nozzle [20]. The nozzle attaches to the water outlet (faucet) and allows the user to obtain an atomized flow of water [20].

4.3 Faucet-Mounted Water Filter: Improving Water Quality

The design in Figure 5 highlights the importance of delivering drinking water that meets preferences for a pleasant taste. The activated carbon/charcoal filter can remove impurities for safety, but also to make the taste of water more pleasant [21]. The purpose of this device supports the idea that the unpleasant taste of tap water does not necessarily relate just to health concerns, but relates in large part to the water not meeting people's general preference for certain water properties like mineral content, etc..

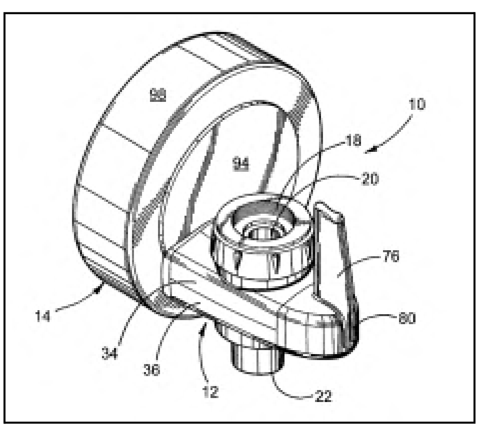


Figure 5. Drawing of a faucet-mounted water filter [22]. The assembly is mounted to the faucet with a threaded inlet (18), and a valve directs water through an activated carbon/charcoal filter [22].

5 Need, Goals and Objectives

This section defines the need, then breaks down this need into goals and objectives.

5.1 Need

There is a need for a system that allows Chestnut residents to fill and clean their water bottles in their dorm rooms in a way that is convenient and pleasant.

5.2 Goals

Goal 1. Provide water that is safe for drinking and washing, with a pleasant taste. If the product increases the risk of unsafe drinking water or water with a bad taste, it is undesirable for residents.

Goal 2. Allow the bottle to be cleaned and filled effectively and conveniently. The ineffective filling of bottles, the awkward angles required to hold bottles in the sink, and the time delays associated are issues experienced by residents, and thus should be improved.

Goal 3. Accommodate various bottles and individual residents' preferences. The spatial limitations in the sink for large bottles were a main source of inconvenience for residents. Individual preference for bottle size and water temperature may vary, and thus should be accommodated.

Goal 4. Be durable enough to withstand the daily use of Chestnut's residents. The system must be able to maintain its functionality and performance quality for regular use, as frequent repairs would be inconvenient and cause further time delays for residents.

5.3 Objectives

Each of the following tables explains objectives corresponding to one goal.

Table 1. Objective Descriptions, Metrics and Justifications for Goal 1.

Goal 1. Provide water that is safe for drinking and washing, with a pleasant taste.			
Objective	**Description and Metric**	**Justification**	**Associated Stake-holder(s)**
1.1	Drinking water provided by the product should not exceed concentrations of 0.156 mg/L chlorine and 125 mg/L calcium.	These are concentration thresholds required for a pleasant taste of water according to the Government of Canada [14]. City of Toronto tap water does not always meet these standards [15, p. 1].	Residents
1.2	Water provided by the product contains zero detectable coliforms per 100 mL.	The system should not contaminate water with bacteria such as coliforms, which can make water unsafe to drink [23]. This is the maximum allowable level set by the Government of Canada for safe drinking water [23].	Residents, UofT S&E

Table 2. Objective Descriptions, Metrics and Justifications for Goal 2.

Goal 2. Allow the bottle to be washed and filled effectively and conveniently.			
Objective	**Description and Metric**	**Justification**	**Associated Stake-holder(s)**
2.1	Requires less than 10 seconds of setup, 10 seconds to switch between filling and washing functions, and 10 seconds to dismantle to return to regular use.	A detour to the cafeteria or to use a water fountain can take approximately 2 minutes, so the improved system should be less time-consuming and thus more convenient.	Residents

2.2	Washing system passes a single-wash assessment as described by ISO 7535:1984 (E), after at most 2 minutes of use [24, p. 3].	Effective washing requires the removal of dirt/soil, which is verified using the single-wash assessment [24, p. 3].	Residents
2.3	Requires zero tools to set up, fill, and clean a water bottle.	It would be inconvenient to require tools, as most residents do not have easy access to tools.	Residents
2.4	Requires at most a pushing/pulling force of 23 N, and a torque of 680 mN·m applied by hands.	Applying large forces is inconvenient. These are maximum allowable forces for palm-operated push-buttons and rotary switches according to MIL-STD-1472H [25, p. 81].	Residents
2.5	Splashing during cleaning, if any, is contained to a radius of less than 15.5 cm.	Splashing would require inconvenient cleanup after each use. Splash radius should be contained to the sink (minimum radius 15.5 cm) or a similarly-sized area.	Chestnut residents, cleaning staff
2.6	Water should be supplied at a flow rate of at least 4.2 L/min.	A sufficient flow rate is necessary to fill/wash in a timely manner. The minimum flow rate is set as that of the Elkay water fountain preferred by students, including the interviewed resident [16].	Residents

Table 3. Objective Descriptions, Metrics and Justifications for Goal 3.

Goal 3. Accommodate various bottles and individual residents' preferences.			
Objective	**Description and Metric**	**Justification**	**Associated Stake-holder(s)']**
3.1	Allows residents to completely fill cylindrical water bottles with dimensions at least up to 30 cm in height and 11 cm in diameter.	These dimensions correspond to the largest bottle sold among the most common bottle manufacturers on Amazon [7, 8, 9, 10].	Residents
3.2	The device should be able to accommodate water temperature in the range 15-49 ºC	Residents may have individual preferences for temperature. Common cold tap water temperatures are approximately 15°C [17]. 49°C is the maximum tap water temperature recommended by the Government of Canada [27].	Residents, UofT S&E

Table 4. Objective Descriptions, Metrics and Justifications for Goal 4.

Goal 4. Be durable enough to withstand the daily use of Chestnut's residents.			
Objective	**Description and Metric**	**Justification**	**Associated Stake-holder(s)**
4.1	Can function properly for at least 1200 filling and washing cycles without replacement parts or maintenance.	This is an estimate of the number of daily cycles repeated over 4 years, which is an approximate maximum number of years students could live in residence.	Residents

4.2	Can withstand a constant water pressure of up to at least 690 kPa without leakage or structural failure [28, p. 29].	Residents who prefer cleaning their bottles with high-pressure water should be able to do so reliably and safely. As per CSA B125.1-18 [28, p. 29].	Residents

6 Conclusion

Staying hydrated in Chestnut residence is less convenient and less pleasant than it could be. Water bottle washing and filling are currently undesirable due to the inconvenience caused by restrictive sink dimensions and unpleasant water quality. Analysis of stakeholder expectations and reference designs revealed the importance of safety, taste, usability, convenience and durability as key aspects that any future solution should address. The NGOs set out in this report provide a guide and starting point to address this opportunity. Hopefully, we may finally quench our thirst for a sip of fresh water out of a conveniently-filled bottle!

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[22] R. Riback, M. Kurth, W. Cowles, and S. R. I. Llc, "US6258266B1 - Faucet mount water filtration device - Google Patents," Apr. 21, 1999. https://patents.google.com/patent/US6258266B1/en?oq=US6258266B1 (accessed Oct. 12, 2025).

[23] Health Canada, "Guidelines for Canadian Drinking Water quality: Guideline Technical Document – Total Coliforms," *Canada.ca*, Sep. 05, 2024. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-total-coliforms.html (accessed Oct. 12, 2025).

[24] International Organization for Standardization, "Surface active agents - Detergents for domestic machine dishwashing - Guide for comparative testing of performance," ISO 7535:1984, Jun. 1984. Accessed: Oct. 12, 2025. [Online]. Available: https://cdn.standards.iteh.ai/samples/14311/fb0302516c3d4d2d9bbfd0f193fa7a91/ISO-7535-1984.pdf

[25] United States Department of Defense, "DESIGN CRITERIA STANDARD HUMAN ENGINEERING," MIL-STD-1472H, Sep. 2020. Accessed: Oct. 12, 2025. [Online]. Available: https://cvgstrategy.com/wp-content/uploads/2023/04/MIL-STD-1472G.pdf

[26] Elkay, "No Lead Two-Level SwirlFlo® Filtered Wall Mount, Barrier-Free Drinking Fountain with EZH2O® Bottle Filling Station Model LZWS-EDFPBM117K," 2015. Accessed: Oct. 12, 2025. [Online]. Available: https://www.elkayfiles.com/spec-sheets/spec00046.pdf

[27] Public Health Agency of Canada, "Water temperature and burns/scalds," *Canada.ca*, Oct. 12, 2011. https://www.canada.ca/en/public-health/services/water-temperature-burns-scalds.html (accessed Oct. 12, 2025).

[28] CSA Group, *Plumbing supply fittings*. 2018. [E-Book]. Available: https://images.thdstatic.com/catalog/pdfImages/49/49651ff2-03b6-40e5-a6b2-0da455977181.pdf

Appendix J. Source Extracts

[1] Health Canada, “Guidelines for Canadian Drinking Water quality: Guideline Technical Document – Total Coliforms,” *Canada.ca*, Sep. 05, 2024. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-total-coliforms.html (accessed Oct. 12, 2025).

1.0 Guidelines

The maximum acceptable concentration (MAC) for total coliforms in water leaving a treatment plant and in non-disinfected groundwater leaving the well is none detectable per 100 mL.

[2] Public Health Ontario, “Drinking Water Quality Indicator Bacteria,” Oct. 2022. Accessed: Nov. 05, 2025. [Online]. Available: https://www.publichealthontario.ca/-/media/documents/f/2019/fact-sheet-drinking-water-quality.pdf?la=en

Q1. What are indicator bacteria?

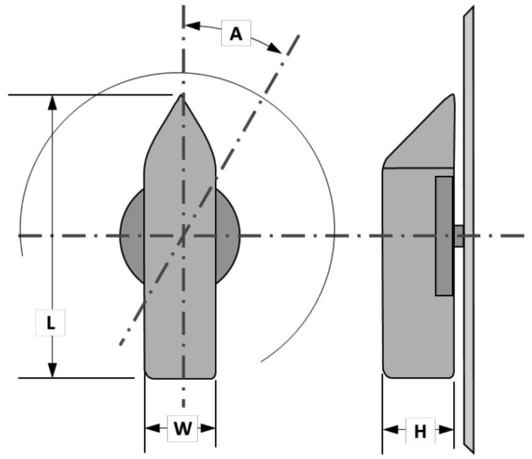
Indicator bacteria are those bacteria that signal contamination in drinking water during testing. The health effects of drinking water that contains indicator bacteria can range from no physical impact to severe illness; e.g., gastrointestinal illness (GI), with symptoms starting within a few hours, days or weeks after consuming the water. GI symptoms can include some or all of the following: nausea, vomiting, cramps, diarrhea, muscle aches, headache and low-grade fever. In rare cases, drinking contaminated water may result in significant illness or death.

Anyone can get sick from drinking contaminated water, but children, the elderly and people with weak immune systems are at a higher risk of the harmful effects.

Q2. What are Total Coliforms and E. coli?

Total Coliforms and *Escherichia coli* (*E. coli*) are indicator bacteria but are also referred to as target bacteria. Other bacteria that may be present in drinking water are called non-target bacteria. The sanitary quality of well water is measured by the amount of target bacteria in drinking water test samples.

[3] United States Department of Defense, “DESIGN CRITERIA STANDARD HUMAN ENGINEERING,” MIL-STD-1472H, Sep. 2020. Accessed: Oct. 12, 2025. [Online]. Available: https://cvgstrategy.com/wp-content/uploads/2023/04/MIL-STD-1472G.pdf



	Dimensions			Resistance
	L, Length	W, Width	H, Depth	
Minimum	25 mm (1 in)	--	16 mm (0.625 in)	115 mN·m (1 in-lbf)
Maximum	100 mm (4 in)	25 mm (1 in)	75 mm (3 in)	680 mN·m (6 in-lbf)

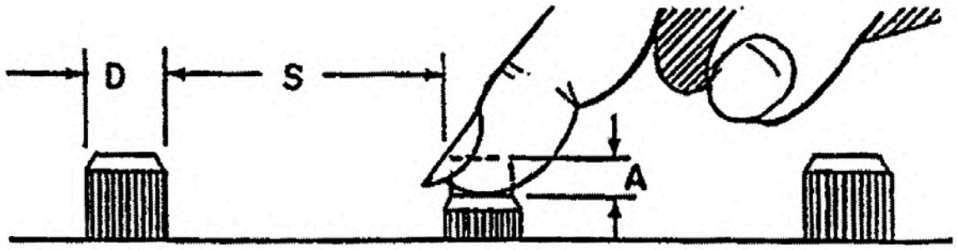
	A, Displacement [1]		Separation	
	--	[2]	One-hand random	Two-handed operation
Minimum	15° (262 mrad)	30° (525 mrad)	25 mm (1 in)	75 mm (3 in)
Maximum	40° (700 mrad)	90° (1,570 mrad)	--	--
Preferred	--	--	50 mm (2 in)	125 mm (5 in)

NOTES:

[1] For facilitating performance.

[2] When special engineering requirements demand large separation or when tactually (“blind”) positioned controls are required.

FIGURE 6. Discrete rotary selector switch.



	Dimensions (D, Diameter)						Resistance		
	Fingertip		Thumb		Palm				
	Bare Hand	Gloved Hand 1/	Bare Hand	Gloved Hand 1/	Bare Hand	Gloved Hand 1/	Single Finger	Different Fingers 2/	Thumb or Palm
Minimum	10 mm (0.4 in)	19 mm (0.75 in)	19 mm (0.75 in)	25 mm (1 in)	40 mm (1.6 in)	50 mm (2 in)	2.8 N (10 oz)	1.4 N (5 oz)	2.8 N (10 oz)
Maximum	25 mm (1 in)	--	25 mm (1 in)	--	70 mm (2.8 in)	--	11 N (40 oz)	5.6 N (20 oz)	23 N (80 oz)

5.6.6.1.7 Location. Heaters shall be located or protected so that personnel cannot touch parts that are hot enough to cause burns (see table XXVII).

TABLE XXVII. Temperature exposure limits.

Exposure	Temperature Limits		
	Metal	Glass	Plastic or Wood
Momentary contact	60 °C (140 °F)	68 °C (154 °F)	85 °C (185 °F)
Prolonged contact or handling	49 °C (120 °F)	59 °C (138 °F)	69 °C (156 °F)

[4] Public Health Agency of Canada, "Water temperature and burns/scalds," *Canada.ca*, Oct. 12, 2011. https://www.canada.ca/en/public-health/services/water-temperature-burns-scalds.html (accessed Oct. 12, 2025).

The upper limit of the objective relating to water temperature comes from the Government of Canada's guidelines on tap water temperature. Here, point 2 describes the upper temperature limit.

Water temperature

Follow these tips for safe hot water temperature:

1. Set the temperature of your water heater to 60°C (140°F) to prevent the growth of harmful bacteria such as Legionella.
2. Prevent scalding by installing automatic mixing valves on faucets, showers, and tubs, or an anti-scald mixing valve on your water heater. These mixing valves should be set to allow a hot water temperature of 49°C (120°F).

[5] CSA Group, "Household Dishwashers," CSA C22.2 NO. 167:23, May 2023. Accessed: Nov. 05, 2025. [Online]. Available: https://online-viewer-techstreet-com.myaccess.library.utoronto.ca/virtualviewer/launchViewer.jsp

15.9 Hose rupture test

15.9.1 Except as specified in 15.9.3, an appliance intended to be installed outdoors shall be tested as specified in 15.9.2 to determine if rupturing of water containing components due to freezing results in a risk of electric shock. As a result of the test, an appliance shall comply with the following, as applicable:

a) A cord-connected appliance shall:

1) Show no obvious wetting (see 15.7.1.5) of any electric component that is likely to occur while being conditioned as specified in 15.9.2;

2) Comply with the abnormal leakage current requirements of 5 MIU in Section 13 while being conditioned as specified in 15.9.2; and

3) Comply with the electric strength requirements in Section 16 after being conditioned as specified in 15.9.2; and

b) A permanently connected appliance shall:

1) Show no obvious wetting (see 15.7.1.5) of any electric component that is likely to occur while being conditioned as specified in 15.9.2;

2) Comply with the electric strength requirements in Section 16 after being conditioned as specified in 15.9.2; and

3) Have an insulation resistance of not less than 50,000 Ω between current-carrying parts and interconnected non-current-carrying metal parts after being conditioned as specified in 15.9.2.

15.9.2 The dishwasher shall be positioned and leveled as intended in use and investigated for wetting caused by leakage from a water carrying hose after 5 minutes of operation under conditions of normal operation. The inlet water pressure to the dishwasher shall be maintained at 275-415 kPa gauge (40-60 psig) for the duration of the test. The following requirements shall apply:

a) For this test, each internal water carrying hose shall have a 6.4 mm (1/4 in) diameter hole drilled in the hose in any location that can result in the solution reaching a live part, film-coated wire, or insulation. If the inside diameter of the hose is less than 6.4 mm (1/4 in), the size of the hole drilled in the tubing shall be equal to the inside diameter of the tubing. One location shall be tested at a time.

b) For internal hose connections, each connection shall be disconnected, one at a time, such that the leakage is directed toward electrical components. One hose connection shall be tested at a time.

[6] "Ultraviolet radiation in the workplace," *ontario.ca*, Nov. 21, 2022. https://www.ontario.ca/page/ultraviolet-radiation-workplace#section-3 (accessed Nov. 30, 2025).

Exposure guidelines

The Ministry of Labour, Immigration, Training and Skills Development's Radiation Protection Service applies the threshold limit values (TLVs) recommended by the American Conference of Government Industrial Hygienists (ACGIH) for occupational exposure to UV radiation. These limits are enforced in Ontario workplaces by the ministry under section 25(2)(h) of the *Occupational Health and Safety Act*. For workplaces in the mining industry, there are specific requirements for protecting workers who perform welding, burning, or cutting operations from radiation and electric arcs. These are found under section 194(3) of R.R.O. 1990, Reg. 854: Mines and Mining Plants.

Exposure limits are based on UV doses that normally do not produce sunburn or eye irritation (such as welder's flash). They consider the varying biological effects of different wavelengths of UV radiation. The guidelines limit the "effective Actinic UV irradiance" to three millijoules per square centimetre, accumulated over an eight-hour period.

Additionally, the total irradiance of "UVA Spectral Region (315 to 400 nm)" on the unprotected eye is limited to 1.0 milliwatt per square centimetre for periods greater than 16.7 minutes and to 1.0 joule per square centimetre for shorter periods. (See Ultraviolet Radiation in the ACGIH's Threshold Limit Values. There is a fee for the booklet.)

[7] Brita, "FAQs," *Brita*. https://www.brita.com/support/faq/replacement-filters/ (accessed Nov. 30, 2025).

It's important to change your filter as recommended for optimal performance. If you have hard water, you may need to change filters more often. Use your cling calendar, or activate your electronic filter change indicator, when you install a new filter to help keep track of your usage. Filter replacement depends on filter and product type.

Pitcher and Dispenser Filters

- Brita® Original (Standard) (White) Filter: Every 40 gallons (about 2 months)
- Brita Elite™ (Blue) Filter: Every 120 gallons (about 6 months)
- Brita Stream® (Gray) Filter: Every 40 gallons (about 2 months)

[8] Government of Canada, Canadian Centre for Occupational Health and Safety, "Ultraviolet radiation," Sep. 11, 2025. https://www.ccohs.ca/oshanswers/phys_agents/ultravioletradiation.html (accessed Nov. 30, 2025).

What are some health effects of exposure to UV radiation?

Back to top

Some UV exposure is essential for good health. It stimulates vitamin D production in the body. In medical practice, one example is UV lamps can be used for treating psoriasis (a condition causing itchy, scaly red patches on the skin).

Excessive exposure to ultraviolet radiation is associated with different types of skin cancer, sunburn, accelerated skin aging, as well as cataracts and other eye diseases. The severity of the effect depends on the wavelength (see Figure 2), intensity, and duration of exposure.

Effect on the skin

The shortwave UV radiation (UV-C) poses the maximum risk. The sun emits UV-C, but it is absorbed in the ozone layer of the atmosphere before reaching the Earth. Therefore, UV-C from the sun does not affect people. Some man-made UV sources also emit UV-C. However, the regulations concerning such sources restrict the UV-C intensity to a minimal level and may require the installation of special guards or shields and interlocks to prevent exposure to the UV.

The medium wave UV (UV-B) causes skin burns, erythema (reddening of the skin) and darkening of the skin. Prolonged exposures increase the risk of skin cancer.

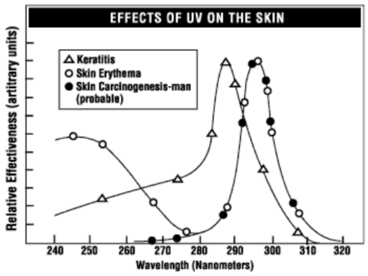


Figure 2 - Relative sensitivity of the eye and the skin to UV radiation of different wavelengths.

Effect on the eyes

The eyes are particularly sensitive to UV radiation. Even a short exposure of a few seconds can result in a painful, but temporary condition known as photokeratitis and conjunctivitis. Photokeratitis is a painful condition caused by the inflammation of the cornea of the eye. The eyes water and vision is blurred. Conjunctivitis is the inflammation of the conjunctiva (the membrane that covers the inside of the eyelids and the sclera, the white part of the eyeball); (see Figure 3) which becomes swollen and produces a watery discharge. It causes discomfort rather than pain and does not usually affect vision.

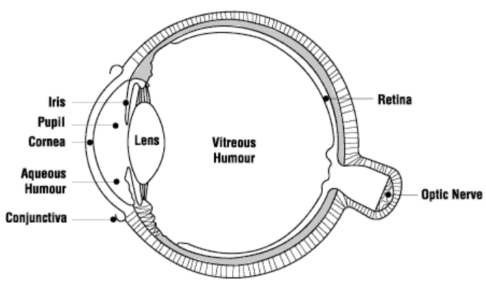


Figure 3 - The eye

Examples of eye disorders resulting from UV exposure include "flash burn", "ground-glass eye ball", "welder's flash" and "snow blindness" - depending on the source of the UV light causing the injury. The symptoms are pain, discomfort similar to the feeling of sand in the eye and an aversion to bright light.

The eyes are most sensitive to UV radiation from 210 nm to 320 nm (UV-C and UV-B). Maximum absorption by the cornea occurs around 280 nm. Absorption of UV-A in the lens may be a factor in producing cataract (a clouding of the lens in the eye).

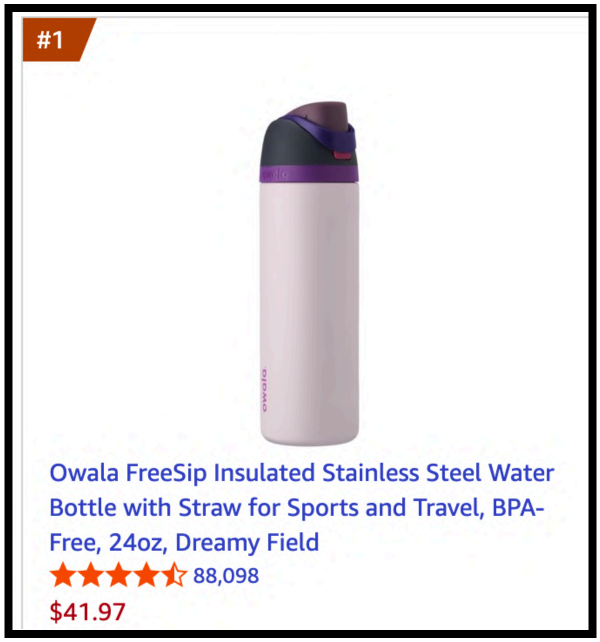
[9] YETI Holdings Inc., “Rambler® 769 ML Bottle WITH CHUG CAP,” *YETI*. https://www.yeti.ca/drinkware/bottles/70000004945.html (accessed Oct. 10, 2025).

DIMENSIONS 4.8"W x 11.6"H (12.2W X 29.5H CM)	RAMBLER® **1.89 L BOTTLE** WITH CHUG CAP **C$85.00**

[10] Amazon Corporation, “Stanley IceFlow 2.0 Flip Straw Tumbler with Handle 40 oz | Twist On Lid and Flip Up Straw | Leak Resistant Water Bottle | Insulated Stainless Steel | BPA-Free | Lilac,” *Amazon*. https://www.amazon.com/dp/B0DR9NTL71?ref=cm_sw_r_cp_ud_dp_2N3ZWVHHYGV6F1GFTZMA&social_share=cm_sw_r_cp_ud_dp_2N3ZWVHHYGV6F1GFTZMA&th=1 (accessed Oct. 10, 2025).

Style	40 Ounces
Recommended Uses For Product	Water
Included Components	Straw
Shape	Cylindrical
Product Care Instructions	Dishwasher Safe
Age Range (Description)	Adult
Material Feature	Bpa Free, Dishwasher Safe
Reusability	Reusable
Item Weight	0.83 Kilograms
Product Dimensions	4.33"W x 11.02"H
Number of Items	1
Manufacturer	Stanley

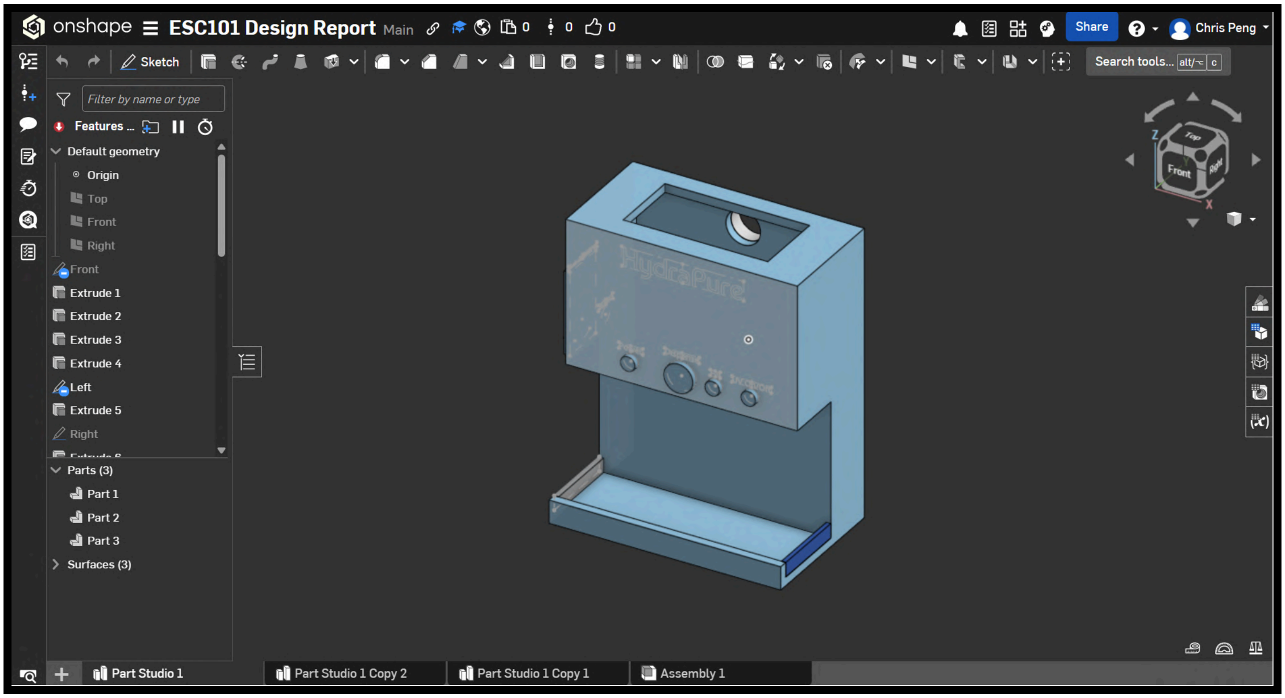
[11] Amazon Corporation, “Amazon.ca Best Sellers: The most popular items in Water Bottles,” *Amazon*. https://www.amazon.ca/Best-Sellers-Water-Bottles/zgbs/sports/2406090011 (accessed Oct. 10, 2025).



[12] A. Musa, S. Saleh, K. Mohammed, Y. Labaran, and J. Yau, "Evaluation of Potential Use of Charcoal as a Filter Material In Water Treatment," *International Research Journal of Engineering and Technology (IRJET)*, vol. 7, no. 5, May 2020, [Online]. Available: https://www.researchgate.net/publication/341387361_Evaluation_of_Potential_Use_of_Charcoal_as_a_Filter_Material_In_Water_Treatment

This research evaluated the contaminant removal efficiency of an improvised charcoal filter. The filter had four layers with 6.3, 2.0, 1.18 mm sized, and powdered charcoal responsible for the filtration process. The water sample was collected from river Challawa from the region believed to have the highest concentration of contaminants. The physicochemical and bacteriological characteristics of the water sample before and after filtration were determined and evaluated. Although testing for coliform bacteria in the samples before and after filtration read positive, the charcoal filter showed very high turbidity removal efficiency (i.e. up to 98%) after a seven-number repeated filtration runs. It also showed high odor, hardness, and chloride removal efficiencies. However, an increase in conductivity was observed in the filtered samples which may be correlated to the ability of charcoal to enrich the water with elements like sodium and potassium. In addition to these the pH value of the sample before filtration was acidic (i.e. 5.7) but increased to 7.7 after filtration which is suitable for drinking water. Hence, it is recommended here that charcoal filters can be used to produce high-quality water.

[13] "OnShape." PTC. [Online]. Available: https://cad.onshape.com/


onshape
ESC101 Design Report Main
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Chris Peng
Sketch
Search tools...
Filter by name or type
Features
Default geometry
Origin
Top
Front
Right
Front
Extrude 1
Extrude 2
Extrude 3
Extrude 4
Left
Extrude 5
Right
Parts (3)
Part 1
Part 2
Part 3
Surfaces (3)
Part Studio 1
Part Studio 1 Copy 2
Part Studio 1 Copy 1
Assembly 1

[14] T.-H. Liang, T.-F. Liang, and Individual, "US20030042337A1 - Connector for a faucet - Google Patents," Aug. 31, 2001. https://patents.google.com/patent/US20030042337A1/en?q=(kitchen+sink+hose+and+sprayer+faucet+attachment)&oq=kitchen+sink+hose+and+sprayer+faucet+attachment&page=4 (accessed Oct. 12, 2025).

Correspondence Address:
ROSENBERG, KLEIN & LEE
3458 ELLICOTT CENTER DRIVE-SUITE 101
ELLICOTT CITY, MD 21043 (US)

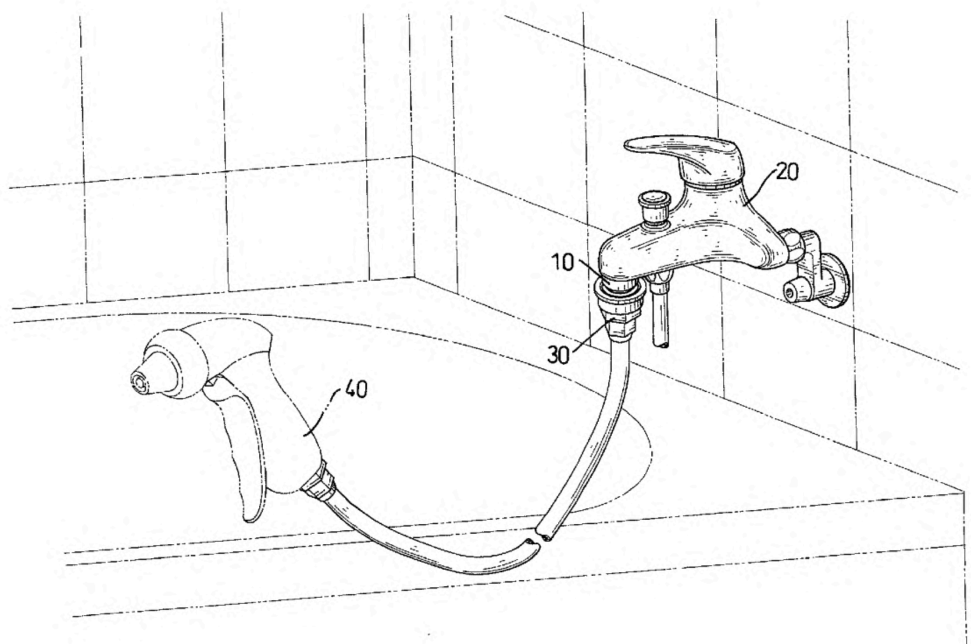
(21) Appl. No.: **09/942,714**

(22) Filed: **Aug. 31, 2001**

Publication Classification

(51) **Int. Cl.**[7] **B05B 7/02**

A connector for a faucet **(20)** is constructed of a faucet-connecting portion **(11)** and a tube-connecting portion **(13)**. The faucet-connecting portion **(11)** further has a thread defined in an inner or outer periphery of the faucet-connection **(11)** to threadingly combine with the faucet **(20)**. The tube-connecting portion **(13)** is adapted to connect with a quick-release hose **(30)** having a spraying device. Therefore, the connector **(10)** communicate between the faucet **(20)** and the quick-release hose **(30)** in an easy manner.



[0005] According to the above description, the kitchen or bathroom faucet **(50)** can not provide water to a further place except a sink where the faucet **(50)** is mounted above. If people want to clean a bathroom or kitchen by spraying water, they have to store the water in the sink and then transfer water by ladle or other containers, so that usage of the faucet **(50)** is inconvenient and limited.

[0006] Therefore, the present invention has arisen to mitigate and/or obviate the drawbacks of the kitchen or bathroom faucets.

[15] University of New Hampshire, “Small Public Water System Technology Guide - UV Disinfection educational module.” https://www.unh.edu/wttac/WTTAC_Water_Tech_Guide_Vol2/uv_lampnsleeve.html (accessed Nov. 30, 2025).

> ***Operation:***
> Lamps require adequate time to warm up before flow begins, typically 2 – 5 minutes. Safety is always a major concern. UV systems are typically sealed but UV light and heat can cause burns and skin and eye damage (Malley et al, 2001). Periodic cleaning of UV reactors (i.e. lamp sleeves) is required because components can become fouled.

[16] B. Robinson, “How to maintain your UV system,” *Fresh Water Systems*, Jun. 02, 2023. https://www.freshwatersystems.com/blogs/blog/how-to-maintain-your-uv-system (accessed Nov. 30, 2025).

> Over the course of the UV lamp's 9,000-hour lifespan, the mercury will slowly deplete as heat continues to be applied to it. After the 9,000 hours have transpired, the effectiveness of the mercury has been exhausted and the light emitted from the lamp will no longer irradiate any microorganisms in the water.

[17] University of Washington, “ULTRAVIOLET (UV) SAFETY,” Sep. 2022. Accessed: Nov. 30, 2025. [Online]. Available: https://www.ehs.washington.edu/system/files/resources/uv-safety.pdf

> **ENGINEERING CONTROLS**
>
> Enclosures, screens, or filter used to contain the UV radiation or devices such as interlocks must be used at all times.
>
> UV can easily be shielded by materials such as polycarbonate, metal, cardboard, and wood. Ordinary glass blocks most UV light of wavelengths less than 330 nm but may also transmit most of the UV for longer wavelengths. It should not be relied for UV protection unless UV shielding is verified. Please check your safety equipment to ensure that it is rated for the wavelength in use.

[18] Crystal IS, “Using UV Reflective Materials to Maximize Disinfection,” Jan. 2025. Accessed: Nov. 30, 2025. [Online]. Available: https://www.cisuvc.com/wp-content/uploads/2024/01/AN011_Reflective_Materials.pdf

Table 1

Material	Reflectivity
e-PTFE	95%
Aluminum-sputtered on glass	80%
Aluminum foil	73%
Stainless steel (various formulas)	20 – 28%

A common material used in commercial UV disinfection systems is stainless steel. While this surface is highly resistive to microbial growth, it only has 20 - 28% reflectance of UV light. Flow cells that contain e-PTFE (expanded Polytetrafluorethylene) provide more than 95% reflectance (as shown in the table above) of the UVC light—making systems constructed of these materials more than three times effective than traditional reactors. The following examples show how using highly reflective materials benefit applications in water and air disinfection.

[19] C. L. Ofstead, K. M. Hopkins, F. E. Daniels, A. G. Smart, and H. P. Wetzler, “Splash generation and droplet dispersal in a well-designed, centralized high-level disinfection unit,” *American Journal of Infection Control*, vol. 50, no. 11, pp. 1200–1207, Oct. 2022, doi: 10.1016/j.ajic.2022.08.016.

Moisture detection methods

Researchers used duct tape to affix large sheets of blue moisture-detection paper (ScopeDry Check, Healthmark Industries; Fraser, Michigan) to environmental surfaces, including the floor, floor mats, counters, walls, leak tester, and irrigation system. In addition, moisture-detection paper was attached to carts positioned 4 feet (1.2 meters) away from the sink (Fig 1B-C). The paths from the sink to the AERs and the sink to the door of the suite were paved with moisture-detection paper to evaluate droplet dispersal from wet endoscope transport cassettes and shoe covers. Labels indicating distance from the sink were affixed to surfaces to facilitate documentation of droplet dispersal. Strips of moisture-detection paper were also affixed to PPE worn by researchers during simulated manual cleaning activities.

Droplet generation and dispersal were documented via photographs taken with a tablet camera (Tab M8HD, Lenovo; Quarry Bay, Hong Kong), observations by researchers, and verbal reports from technicians standing within the splash zone. Two independent researchers counted droplets visible in photos of moisture-detection paper adhered to PPE and environmental surfaces. The endpoints were droplet generation, droplet dispersal, and PPE exposure and effectiveness for the technician at the sink and other nearby personnel.

[20] Aquatherm, “AQUATHERM AND HIGH RISE CONSTRUCTION - Aquatherm,” *Aquatherm*, Oct. 17, 2018. https://aquatherm.com/tech-bulletins/aquatherm-and-high-rise-construction (accessed Nov. 30, 2025).

There are two different trains of thought in design of high-rise building water systems. One is to pump the water from the lowest floors up to a storage tank with a float valve in it on the highest floor or roof and then let the height of the building provide the pressure to the lower floors. The problem with this type of system is that the highest floors, usually the high rent floors, will have the lowest water pressure with the highest floor, the penthouse, not having much pressure at all! This type of system also means that you have to provide pressure reducing valves to maintain code compliance for the water pressure on the lower floors.

[21] Code of Federal Regulations, "Appendix S to Subpart B of Part 430, Title 10 -- Uniform test method for measuring the water consumption of faucets and showerheads," May 24, 2023. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20S%20to%20Subpart%20B%20of%20Part%20430 (accessed Nov. 30, 2025).

3.2. Using the Time/Volume Method To Measure Flow Rate

There are several additional requirements when measuring flow rate downstream of a showerhead or faucet as described in section 5.4.2.2(d) of ASME A112.18.1 to measure flow rate. First, ensure the receiving container is large enough to contain all the water for a single test and has an opening size and/or a partial cover such that loss of water from splashing is minimized. Second, conduct the time/volume test for at least one minute, with the time recorded via a stopwatch with at least 0.1-second resolution. Third, measure and record the temperature of the water using a thermocouple or other similar device either at the receiving container immediately after recording the mass of water, or at the water in the supply line anytime during the duration of the time/volume test. Fourth, measure the mass of water to a resolution of at least 0.01 lb. (0.005 kg) and normalize it to gallons based on the specific gravity of water at the recorded temperature.

[22] University of Toronto, "Sessional Dates | Faculty of Applied Science and Engineering," 2025. https://engineering.calendar.utoronto.ca/sessional-dates (accessed Nov. 30, 2025).

September 2	U of T Engineering F-term and Y-term courses begin. Arts & Science F-term and Y-term courses begin.

April 9 to April 30	Exams for S-term and Y-term U of T Engineering courses. Exams for S-term and Y-term Arts & Science courses. Note: Exams for courses offered by other faculties may be held outside of this period.

[23] Chestnut Residence at the University of Toronto, "Home - Chestnut Residence at University of Toronto," *Chestnut Residence at University of Toronto*, Sep. 24, 2025. https://chestnut.utoronto.ca/ (accessed Nov. 30, 2025).


A DIVERSE COMMUNITY
Who lives at Chestnut?
Chestnut Residence is home to nearly 1150 students from all University of Toronto faculties and colleges.
75% FIRST YEAR STUDENTS
Making it an excellent place to make new friends during your first year of your undergraduate career.
INTERNATIONAL STUDENTS
We house the highest number of international students across the University.
ENGINEERING STUDENTS
We house the highest number of Engineering Students across the University.