3-D Printing: A New Approach to Water Filtration

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Introduction/Background

People often find themselves in situations where clean drinking water is not readily available. In the United States, these situations often arise while hunting, camping, or engaging in other various activities. In developing countries, particularly rural areas, potable water is a scarce resource. One solution to this problem is the use of 3-D printed water filters.

Key Points

- Nearly 1 billion people in the developing world do not have access to potable water.
- Suffering caused by water-borne diseases and time lost gathering water restrains the local people's productivity.
- Economic development is lost while people merely try to survive.
- Additive manufacturing, the process behind 3-D printing, offers an alternative solution to this problem.
- 3-D printers are becoming more common and publicly accessible.
- 3-D printed water filters will be a cheaper, smaller alternative.
- Filter designs will be purchased off the Internet and manufactured at a local vendor.

Objective

This project's **primary objective** is to test the usability of 3-D printed water filters.

- The filters will be designed with AutoCAD software and manufactured in a 3-D printer.
- Laboratory tests will conducted to measure the performance of the water filters.
- Performance considers the permeability, turbidity removal, and bacteria removal.

Project Aspects

Design.

Water filters are designed in individual 0.024 mm thick layers, then stacked together in a vertical series (about 20 mm tall)

Performance.

Permeability: The rate of water flow through each filter over a certain period of time. Expressed as the coefficient of permeability (k) in cm/minute.

Turbidity Removal: Turbidity is the cloudiness of water due to suspended and dissolved solids. Tests are run to determine the filters' minimum particle removal size.

Bacteria Removal: Material and coatings research will be conducted to remove *Escherichia coli* (*E. coli*) bacteria.

Survey

Its **purpose** is gauge the public's acceptance to the utilization of 3-D printed water filters. The survey consists of three components:

(1) Statements- Answered in range strongly disagree-neutral-strongly agree.
(2) Demographics- Personal questions to classify surveyee.
(3) Open Statements- Questions to incite opinion-based responses.

Materials

3-D printed water filter, Hand-made 1.0 Liter SmartWater water bottle reservoir, Crumb Rubber Modified (CRM) shavings, Mesh sieves (No. 20, 30, 40, 60, 80, 100, 200), HACH 2100N Turbidometer, turbidity test vials, general lab equipment.

Testing Procedures

Manufacture Turbid Water.

(1) CRM shavings are screened according to particle size with arranged mesh sieves. Specific sizes mentioned above.
(2) Potable water is mixed with CRM screenings from each sieve. The initial particle concentration is 50 g/L.
(3) The turbid water particle sizes are 841, 595, 420, 250, 149, and 74 microns.

Source: http://www.pavementinteractive.org

Figure 1: Standard Sieve Stack

Source: http://www.sigmaaldrich.com

Figure 2: Particle Size Conversion Table

Measure Permeability of Filter

(1) Water bottle reservoir, with attached water filter, is set to allow water flow into a beaker. Two lines are marked on the filter, 21.4 cm and 7.4 cm, to measure initial and final head.
(2) The reservoir is filled with water. A stopwatch measures the amount of time required for water level to drop from 21.4 cm to 7.4 cm mark.
(3) The process is repeated three times to determine average time.
(4) Equation 1 is used to calculate the coefficient of permeability (k).

Equation 1: $$\mathbf{k} = \frac{A_1 * L}{A_2 * t_{avg}} * \ln\left(\frac{h_2}{h_1}\right)$$

Measure Turbidity Removal

(1) Each turbid water is stirred and poured into a turbidity test vial. The test vial is continually stirred before being placed into the turbidometer, which measures initial turbidity.
(2) The test vial's contents are then poured into the water bottle reservoir through the water filter and collected in a beaker.
(3) The collected water is poured into a turbidity test vial and placed into the turbidometer, which measures final turbidity.

Figure 3: Unfiltered Water

Figure 4: Filtration Process

Figure 5: Filtered Water

Results

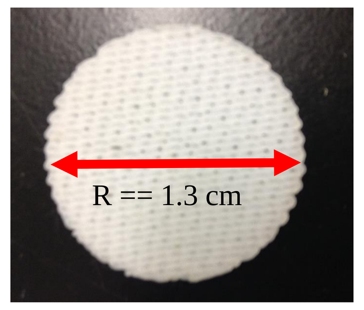

Figure 6: Plan View

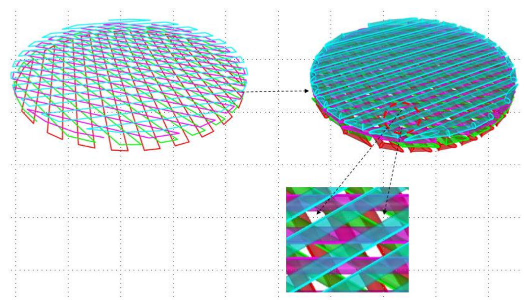

Figure 7: AutoCAD Design of Filter

Permeability

Three tests yield t = 31.9 s, 31.6 s, 3.8 s. Implies t_{avg} **= 31.77 secs**

Use *Equation 1*, where A_1 = cross-sectional area of filter, A_2 = cross-sectional area of bottle, L = vertical length of filter, t = time, h_1 = initial head, h_2 = final head.

$$\mathbf{k} = \frac{\frac{\pi}{4} * (7.4\ cm)^2 * 0.2\ cm}{\frac{\pi}{4} * (1.3\ cm)^2 * 31.77\ secs} * \ln\left(\frac{7.4\ cm}{21.4\ cm}\right)$$

$$= 2.16\ x\ 10^{-1}\frac{cm}{s} = 12.96\frac{cm}{minute}$$

The coefficient of permeability calculated to be **12.96 cm/minute**.

Turbidity Removal

Table 1 shows the water filter's performance in removing turbidity.

Note: At No. 100 sieve, flow rate slowed significantly due to plugging.

Table 1: Turbidity Removal Results

Sieve Size	Nominal Size Opening (microns)	Initial Turbidity (NTUs)	Final Turbidity (NTUs)	Conclusion (RAP = removed all particles)
No. 20	841	24	0	R.A.P.
No. 30	595	34	0	R.A.P.
No. 40	420	38	0	R.A.P.
No. 60	250	47	0	R.A.P.
No. 80	177	52	0	R.A.P.
No. 100	149	56	0	R.A.P.
No. 200	74	62	0	R.A.P.

Survey Statements

1- Consciously felt the need for a water filter in past experiences.
2- Convenient to use a local vendor to print a water filter design.
3- A small, easily transportable water filter is preferable.
4- Eco-friendly, recyclable materials are preferred in filter's design.

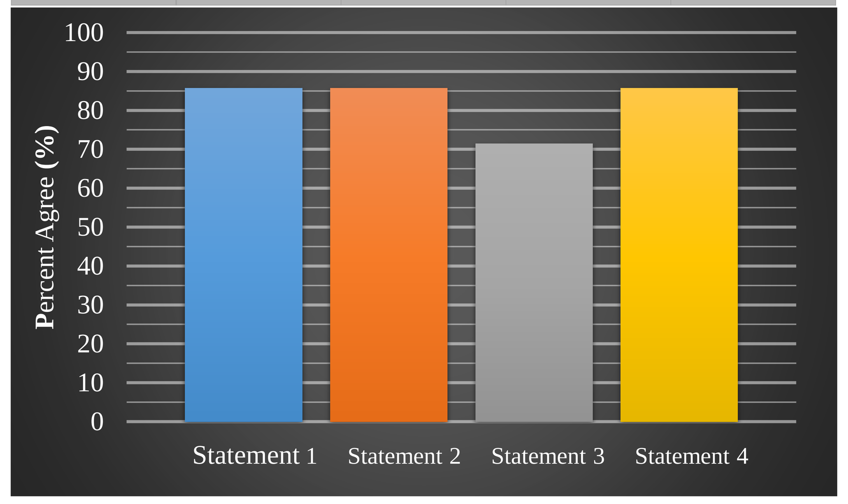

Figure 8: Results of Survey

Conclusions

Permeability

The coefficient of permeability was calculated to be 12.96 cm/min. Using general flow rate equation **Q = k * A**, the water filter allows a maximum flow rate of 17.23 cm^3/min. At this rate, 1.0 liter of water will be filtered in 58 minutes.

Turbidity Removal

Results from *Table 1* show the water filter can remove particle sizes as small as the No. 200 sieve, or 74 microns. This corresponds with conventional particle filtration (5 – 1000 microns).

Survey

Figure 8 portrays that over 85% of the surveyed population have consciously needed a water filter. Also 85% feel comfortable using a convenient local vendor to print a water filter design.