Development of water filters using plant xylem

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Introduction

According to the World Health Organization, 1.1 billion people worldwide do not have access to safe drinking water and 5 million die annually due to poor drinking water quality. Although numerous water filtration devices are available worldwide, there is a lack of pocket-friendly alternatives for the poorer communities. Transportation of water and nutrients in plants occurs through a bundle of vascular tissues called xylem. The xylem in coniferous trees consists of tracheids (a few mm-cm long) the walls of which are interspersed with pit membranes. Composed of an impermeable torus and a permeable margo, these pits prevent the passage of nucleated bubbles. The effective margo pore size ranges from nm to pm, making the xylem a promising candidate for low-cost water filtration.

Experimental setup

| Pressure | 5-10 psi |
| Cross section | ~1 cm² |
| Flow rate | 20-40 mL/min |
| Wood samples | Pinus Strobus (Eastern White Pine) |

Filtration characteristics

Fluorescein-labeled inactivated E.Coli (~1 μm in size) were passed through the filter. 99.99% bacterial rejection was observed. Further, SEM images revealed that the pit membranes help trap bacteria.

Xylem length versus rejection

While longer xylem samples would lead to lower flow rates due to increase in flow resistance, samples that are too short (smaller than the length of the tracheids) would have poor filtration characteristics. As it is important to strike an optimal balance, tests were conducted by passing a dye solution through different lengths of xylem (0.2″-1″). Sample cross sections showed that the dye did not penetrate beyond the first 0.1″[8].

Wood samples:

Cross section: ~1 cm
Pressure: 5-10 psi
Flow rate: 20-40 mL/min
Wood samples: Pinus Strobus (Eastern White Pine)

Xylem preservation

Wood samples, when left in the open, tend to dry up resulting in clogging of the pit membranes. Under these conditions, the xylem does not allow any water to flow through or the flow rates obtained are extremely low. This would be a serious concern if the filters are to be transported and stored before usage.

A protocol was developed to preserve the structure of the xylem by keeping the pit membranes intact such that the flow rates are regained after the drying process. A comparison of the structure of the torus-margo pits obtained through SEM imaging is presented below.

The graph below demonstrates the effectiveness of the preservation protocol. Tests were conducted at 10 psi for samples 0.25″ long. The weights of the samples were periodically monitored to ensure that they were completely dry before testing.

Significance of sampling location

The low flow rates in blunt branches indicate that plants have an active mechanism to shut out water transport/supply to functionally redundant regions.

Conclusion

The pit membranes in the xylem of coniferous trees are capable of achieving 99.99% rejection of E.Coli which makes xylem a promising candidate for the development of low cost water filters. As experiments indicate that filtration takes place in the first 0.1″ of the samples, these filters have the potential to be small and compact.

A preservation protocol to preserve the flow rates of xylem filters after drying was developed. Experiments conducted showed that the xylem structure is preserved without any compromise on rejection ability. This would significantly aid transportation and storage of xylem filters. The xylem presents inspiring prospects for an environment-friendly alternative for water filtration in regions where the risk of water-borne diseases is high and affordability is a concern.

References

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