Comparative study of filtrates through different xylem of plants

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Abstract:

Plants possess xylem tissue, a crucial conduit for water and nutrient transport that supports plant growth and survival. To comprehend plant physiology and its responses to varying environmental conditions, we must gain insights of filtration properties of xylem tissue.

The present study is focused on filtering of the contaminated water using the xylem tissue of plant. The xylem filters are made from different trees Ashoka, Mango, Jamul (Malabar plum), White Water Apple.

To achieve this, we employ an innovative approach involving the addition of a pump to increase pressure, subsequently enhancing the flow rate through the xylem. As the filtrate traverses the xylem tissue, we closely monitor physical parameters (Total Dissolved Solids, pH, Turbidity) and chemical parameters (Total Hardness, Chloride, Nitrate, Sulphate, Iron, Mercury, Cyanide, Chromium). This comprehensive analysis allows us to evaluate the xylem's efficacy in filtering and purifying the water it transports.

1. Introduction:

The idea of filtration by a plant xylem was given by Boutilier et. al., using the branches of pine tree having diameter 0.5 inch and length1 inch. They performed the experiments with the solution of the pigment of dye having the size of particles of the range of 70-500 nm in water. It was shown that xylem of plant is capable to remove out larger particle and allow to pass smaller particles of ink. They found that 99.99% of E. coli. bacteria of 1 µm was rejected using xylem of pine tree. It was observed that the sample of 0.25inch length of pine tree was sufficient to reject the bacteria of size 1 micro level. It was also found that, for the particles which are below the size of 100 nm, the rejection rate was increased with the length of the sample. The xylem exhibits the different permeability and rejection rate with the direction of the feed solution. The xylem tissue of gymnosperms has evolved to have pores of an ideal size for filtering out waterborne pathogens. It was found that the Pinus tied filter rejected 95% to 96% of inactivated Escherichia coli. The rejection of micron-sized particles of microorganisms are responsible for waterborne diseases such as protozoans.

Xylem is the conducting tissue that is found in plants which is responsible for the transport of water and minerals from roots to different parts of the plants. The size of the xylem pores is of about few nanometres (nm) to 500nm.These pores are allowed to transfer the desirable materials in the plants like nutrients, salts and minerals, rejected the undesirable larger particles like bacteria and viruses. This also provides mechanical support due to presence of lignin at the site of cell wall. It supports the weight of about 15–20 kg/mm2. It is most abundant biological tissue on earth. It is the dead tissue that is why it functions outside the plant body as a sieve (filtering element). If it is not a dead tissue, then it will not functional outside the body of living plants.

2. Problem statement:

Clean water is the basic need for survival of human on the earth, its scarcity leads to mortality especially in the developing nations. The drinking water is one which is free from pathogen, and possess desirable physical and chemical properties needed for human.

On June 2022, WHO stated that about 5.9 billion people around the world are being used water from safe and improved sources which is 87% population of the world. In 2020, it was estimated that about 5.3 billion people (71% of total population) exploit the services of the water which is safe and drinkable, easily available in local areas.

There are so many common technologies which are available for us to disinfect contaminated water like pasteurization, chlorination and Ultra Violet disinfection. Xylem is the conducting tissue found in the plants which is responsible for the transport of water and minerals from roots to different parts of the plants, hence xylem can be act as filter for the purification of contaminated water.

3. Literature review:

Boutilier, M. S. H., Lee, J., Chambers, V., Venkatesh, V., & Karnik, R. (2014). "Water Filtration Using Plant Xylem".

Boutilier et al. investigate the possibility of using plant xylem as an organic water filtering system. The small pores of xylem, the tissue in plants that transports water, may be able to filter impurities out of water. The goal of the study is to determine whether xylem membranes may be used to purify water in an economical and environmentally friendly way. He also observed that the ability of xylem to remove bacteria was tested using rod-shaped, 1 µm Escherichia Coli bacteria and a rejection of at least 99.99% was observed.

Potash, B. R. (2014). "Characterization and Preservation Techniques of Plant Xylem as Low-Cost Membrane Filtration Devices".

Potash's study endeavours to enhance the utilization of plant xylem as membrane filtration devices by comprehending and conserving its characteristics. The objective of the research is to investigate the anatomical and functional characteristics of xylem and devise methods to augment its effectiveness and durability in water filtration uses. Potash conducts a number of tests to look at different aspects of xylem membrane function, such surface properties, porosity, and pore size. The study also looks at ways to keep xylem membranes intact so that they don't deteriorate and can last longer.

Tyree, M. T., & Sperry, J. S. (1989). "Vulnerability of Xylem to Cavitation and Embolism".

The research by Tyree and Sperry explores how susceptible xylem, the plant tissue in charge of water transport, is to embolism and cavitation. Air bubbles in xylem pipes can create cavitation, which is the disruption of water flow, and embolism, which is the term for obstructions brought on by air bubbles. The authors investigate the variables that affect xylem susceptibility through experimental study, such as temperature fluctuations, water stress, and channel structure. The study clarifies how plants control water transport to endure environmental obstacles by comprehending these systems.

Chen, F., Gong, A. S., Zhu, M., Chen, G., Lacey, S. D., Jiang, F., ... & Hu, L. (2017). "Mesoporous Three-Dimensional Wood Membrane Decorated with Nanoparticles for Highly Efficient Water Treatment".

Chen et al. build three-dimensional wood membranes embellished with nanoparticles to demonstrate a novel method of treating water. The goal of the project is to create a sustainable and effective technique of water purification utilizing wood and other renewable resources. Through a mix of performance testing and materials synthesis, the researchers show how well their wood-based membrane works to filter impurities out of water. The membrane maintains its environmentally friendly qualities while achieving improved filtering capacities thanks to the incorporation of nanoparticles into the wood structure.

4. Schematic diagram:

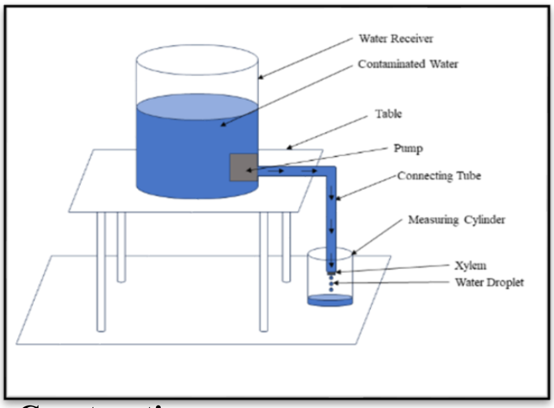

Figure 1:- Schematic diagram of model

5.

1. Begin by selecting healthy Ashoka, mango, guava, jamun, and neem plants for the experiment.
2. Cut a 10 cm section from the selected plants, ensuring to remove any leaves or branches from the stem.
3. Cut a small section (2.5 cm in height and 2 cm in diameter) of xylem tissue from the stem of each plant (Aiming for a diameter close to 2 cm as possible).
4. Utilize a 3-liter bucket and drill hole with a 2 cm diameter, positioned 2.5 cm from the bottom of the bucket.
5. Attach 2 cm diameter pipes to the hole in the bucket.
6. Install a pump (40W) in the system to regulate and enhance the flow of water through the xylem tissues.
7. Connect clear plastic tubing to the end of each pipe to collect the water that passes through the xylem tissue.
8. Place the tubing over a measuring cylinder to quantify the volume of water collected.

Figure 2:- Xylem filter

6. Meth

1. Set up the experiment using xylem tissue, pipes, and tubing as directed.
2. Fill the bucket with water, making sure there are no air bubbles in the tube.
3. Turn on the 40-watt pump in order to increase the flow rate.

4. Measure the volume of water that passes through the xylem tissue into the measurement cylinder.
5. Repeating the experiment at various time intervals, recording the volume of filtered water each time.
6. Evaluate the filtration ability of Ashoka, Mango, White water apple and Jambul xylem tissues using the volume of filtered water.
7. Draw conclusions on the optimal plant xylem tissue for water filtering.

7. Collection of filtrates and contaminated water:

Figure 3:- Collection of filtrates & contaminated water

8. Xylem condition analysis:

Table 1:- Comparative Analysis of Xylem Condition Before and After Use

Sr. No.	Sample	Before Use (First Xylem)	After Use (Inner Side)	After Use (Outer Side)
1	Ashoka			
2	Mango			
3	White Water Apple			
4	Jambul (Malabar plum)			

9. Filtration Performance of Various Plant Xylem:

The all-filtered water and contaminated water is tested and certified by Kalpin Watertech Lab.

Table 2:- Physical parameters test report

Sr. No	**Test Parameters**	**Units**	**Contaminated water**	**Ashoka**	**Mango**	**White water Apple**	**Jambul (Malabar plum)**	**Acceptable limit**	**Permissible limit**
1	Total Dissolved Solids (TDS)	mg/L	631	362	329	374	349	500	2000
2	pH	-	9	8	7	8	7	6.5-8.5	6.5-8.5
3	Turbidity	NTU	2	0.5	0.8	1	0.6	1	5

The table 2 shows the test report of physical parameters of a comparison analysis of filtrates collected from different plants of xylem samples. Total Dissolved Solids (TDS), pH and Turbidity are among the parameters was measured. The table 2 shows the how these physical parameters vary between different plant filtrates, showing difference in the quality of the water. For every standard, acceptable limits and allowable limits are given as standards for analyzing the quality of the water.

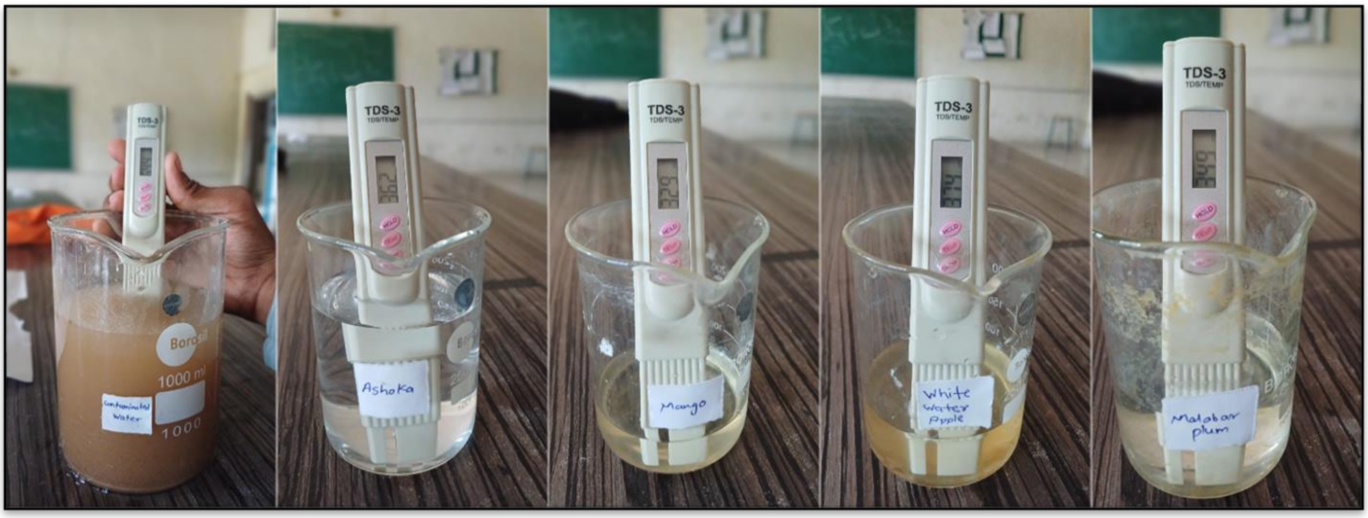

Figure 4:- TDS Levels of Contaminated Water and filtrates

Sr. No	Test Parameters	Unit	Contaminated water	Ashoka	Mango	White water Apple	Jambul (Malabar plum)	Acceptable limit	Permissible limit
1	Total Hardness (CaCO3)	mg/L	210	174	187	136	114	200	600
2	Chlorides (as CI)	mg/L	252	193	116	158	182	250	1000
3	Sulphates (as SO4)	mg/L	40	14	21.8	32	22	45	45
4	Iron (as Fe)	mg/L	0.2	0.04	0.12	0.06	0.18	200	400
5	Mercury (as Hg)	mg/L	<0.001	<0.001	<0.01	<0.001	<0.001	0.3	0.3
6	Cyanide	mg/L	0	0	0	0	0	0.01	0.001
7	Cadmium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.05
8	Chromium	mg/L	0.01	<0.01	<0.05	0.01	0.02	0.02	1.5
9	Nitrate	mg/L	20	10	15	17	17	0.01	0.02

The table 3 shows the test report of chemical parameters of a comparison analysis of filtrates collected from different plants of xylem samples. Total hardness, iron, mercury, cyanide, sulphates, cadmium, chromium, and nitrate are among the parameters was measured. The table 3 shows the how these chemical parameters vary between different plant filtrates, showing difference in the quality of the water. For every standard, acceptable limits and permissible limits are given as standards for analysing the quality of the water.

10. Conclusion:

Xylem tissue of the plant possess membrane like structure in nano scale (few nm to 500 nm) which allows desirable bio-molecules, minerals & salt and rejects undesirable bacteria and viruses. Hence, it acts as a filter-to-filter solution. The sample solution (contaminated water) was passed through xylem pores and filtered water was collected. We concluded from our experiments.

Xylem filter made from the different trees like Asoka, Mango, White Water Apple and Jambul was used for filtration of contaminated water. As the filtrate traverses the xylem tissue, we closely monitor physical parameters (Total Dissolved Solids (TDS), pH, Turbidity) and chemical parameters (Total Hardness, Chloride, Nitrate, Sulphate, Iron, Mercury, Cyanide, Chromium).

After analysis of both the physical parameters and chemical parameter, it can be concluded that the filtrates collected from different plant of xylem exhibits variation in their characteristics.

So, the filtrate obtained from different xylem filters is drinkable. Minerals are not lost during the filtration process and are within the acceptable limit for health concerns.

11. References:

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