

Alternative Water Filters from Mango Tree (*Mangifera indica*), Pomelo Tree (*Citrus maxima*) and Sampaloc Tree (*Tamarindus indica*) Xylems

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Abstract—This study aimed to determine the river water quality of the Lungsungan River, evaluate the treated water samples using alternative water filters constructed from the xylem (wood) of mango (*Mangifera indica*), pomelo (*Citrus maxima*), and sampaloc (*Tamarindus indica*) trees, and compare the laboratory results against the 2017 PNSDW. Microbial analysis revealed that the mango, pomelo, and sampaloc xylem filters exhibited 0% removal efficiency for both total coliform and heterotrophic plate count bacteria. For thermotolerant coliforms, the removal efficiency averaged 51.9% for mango, 19.0% for pomelo, and 28.9% for sampaloc xylem. Physicochemical analysis showed that the xylem filters achieved 0% removal efficiency for arsenic, lead, nitrate, and residual chlorine. Cadmium removal varied: -600% for mango, 0% for pomelo, and -50% for sampaloc. Color removal was 100% effective for all three xylem types. Turbidity removal averaged 81.89% for mango, 82.05% for pomelo, and 81.95% for sampaloc xylem. TDS removal showed a slight increase with average values of -8.25% for mango, -7.39% for pomelo, and -10.12% for sampaloc. The pH values were 7.2 for mango, 7.53 for pomelo, and 7.13 for sampaloc. Despite some laboratory results passing, only total coliform, thermotolerant coliform, and heterotrophic plate count levels did not meet the 2017 PNSDW standards in the drinking water. The One-Way ANOVA analysis showed no significant difference in terms of total coliform, heterotrophic plate count, arsenic, lead, nitrate, color, turbidity, pH levels, total dissolved solids, and residual chlorine results. However, there is a significant difference in at least two xylem types in terms of thermotolerant coliform / *E. coli* and cadmium results, but the post-hoc analysis indicates that the mean cadmium level in mango xylem is significantly higher than both pomelo xylem and sampaloc xylem. Based on the study findings, further research into gymnosperm trees that are local in the Philippines is recommended, such as benguet pine (*Pinus kesiya*), mindoro pine (*Pinus merkusii*), and amboina pine (*Agathis dammara*) instead of angiosperm trees, further research should modify filters with gymnosperm xylem for better bacterial removal. Investigate the cadmium increase in mango and sampaloc xylem filters.

Keywords— Lungsungan River; Water quality assessment; Xylem-based water filtration; Mango (*Mangifera indica*); Pomelo (*Citrus maxima*); Sampaloc (*Tamarindus indica*); Microbial contamination; *E. coli* removal efficiency; Gymnosperm xylem filters; Sustainable water purification; Multidisciplinary environmental study.

I. INTRODUCTION

Drinking water is an essential and irreplaceable aspect of human life. The continual increase in population and urbanization has amplified the demand for clean and potable

water, which has surged. The criteria for potable water have evolved significantly over time. Historically, water was required to be flowing and clear. However, the escalating demands of industrialization, urbanization, and population growth have necessitated stricter water quality standards for environmental and human health protection (Pavendan et al., 2011). According to Sunday et al. (2014), potable water is water that is safe to drink since it is devoid of disease-causing germs and harmful chemical components. For both culinary and drinking uses, water is appropriate (from both health and aesthetic considerations) (DENR, 1994).

The World Health Organization (2023) estimates that 1.8 billion individuals who drink untreated water are at risk of contracting typhoid, dysentery, cholera, and polio. The exposure to these diseases, around 842,000 deaths yearly, is caused by poor sanitation and poor hygiene. According to UNICEF 2017 figures, 53% of Filipino homes do not have access to a safe water source, while 39% do not have access to safe sanitation facilities. The situation is more critical in schools, where 55% of institutions have access to a secure water supply and 26% lack sanitation. According to Environmental Management Bureau Region 9 (EMB IX, 2022), an annual regional report on water quality status was made on water quality monitoring within Zamboanga City. The overall results showed that all waterbodies program conforms with the Standard of Water Quality Guidelines of DAO 2016-08 except the parameter for phosphorous under the Priority River Program, which showed 100% non-conformity, as well as the bacteriological analysis for the parameter fecal coliform in waterbodies program showed non-conformity with the updated water quality guidelines of DAO 2021-19.

This paper explores a potential solution in our environment, specifically in trees containing plant xylem – a porous material that conveys water and dissolved minerals in plants (Conaway, 2023). Plants have developed specialized xylem tissue to transport water and nutrients from their roots to their shoots. Xylem has a conduit structure that is interconnected to one another through spores present in their sidewalls (Karnik et al., 2021). The pores are microscopic, measuring a few nanometers (nm) in angiosperms to a few hundred nanometers (nm) in gymnosperms, roughly 3 to 500 nanometers (nm) wide, depending on the plant species, which has a higher potential to filter out pathogens. With this discovery, plant

xylem can be used as an inexpensive, biodegradable hyper-local water filtration (Shadow Habitat, 2021). The plant xylem has been extensively studied regarding sap transport using white pine trees, the plant xylem is achievable by combining inexpensive and biodegradable materials into a xylem filter. There are no existing studies on using the plant xylem of the mango tree (*Mangifera indica*), pomelo tree (*Citrus maxima*), and sampaloc tree (*Tamarindus indica*).

Therefore, the research aims to investigate its efficacy and efficiency when used to filter water (Boutillier M. et al., 2014). This study used plant xylem as the water filtration device, and the water quality assessment was based on the criteria outlined in the Philippine National Standards for Drinking Water 2017. The parameters considered include the following but are not limited to thermotolerant coliform, total dissolved solids, nitrate, arsenic, lead, color, cadmium, pH, and turbidity. This study collected water samples from the river source in Phase 1, Brgy. Lunzuran, Zamboanga City.

II. METHODOLOGY

2.1 Secondary Data Gathering

Secondary data were obtained from the Department of Health Administrative Order No. 2017-0010, which outlines standards and parameters. Additional information was sourced from books, journals, Research Gate, and Google Scholar.

2.2 Research Locale

The experimental study was conducted at the researcher's private residence in Phase 2, Lunzuran, Zamboanga City, Zamboanga Del Sur, Philippines. This environment provided the researcher with exclusive control and oversight over the experiment.

2.3 Source of Water / Study Area

The Lungsungan River, situated in Phase 1, Upper Lunzuran, Zamboanga City, serves as the primary water source for the study. The river is positioned across a road and surrounded by residences. The river is located on a downhill terrain and is also used as a pathway for motorcycles to reach the other side of the river, and it is also used to wash jeepneys and motorcycles. The river water is visibly turbid

2.4 Collection of Water Samples for Testing

The water samples were collected from the Lungsungan River. The water samples were collected in triplicate over a three-day period. Each experimental setup requires five (5) liters of water, resulting in a total daily collection of fifteen (15) liters. One (1) 100-ml water sample in a sterilized bottle and reagent undergoes testing for bacteriology testing, and one (1) liter of water sample in a PET bottle undergoes physicochemical testing. The influent and effluent were collected and analyzed at Zamboanga City Medical Center Laboratory (ZCMC Lab).

2.5 Water Sample Collection and Analysis Schedule

The water samples were collected from the river Phase 1, Upper Lunzuran, Zamboanga City, from December 5-6, 2024. The water samples were collected from 8:00 am to 10:30 am. The water is visibly clear within the two-day duration of

collection. Two 20-liter buckets of river water were collected every sampling period; one (1) 100 ml of water and one (1) liter of water sample were collected for both influent and effluent and tested at Zamboanga City Medical Center Laboratory for both physicochemical and bacteriological analysis. Among the factors taken into account are the temperature tolerance of coliform, total dissolved solids, nitrate, arsenic, lead, color, cadmium, pH, and turbidity.

2.6 Fabrication of Experimental Setup

The experimental setup comprised one (1) plastic bucket as a container for feed water. A rubber pipe, 1.27 centimeters in diameter and 0.7 meters in length is used to transport the water from the feed to the filter. A clear case, 4 centimeters in diameter and 5.08 centimeters in length, was improvised to be used as a placeholder for the xylem. A hose adapter, 1.24 centimeters hose adapter is used as a channel between the clear case and the rubber pipe. A glue gun and glue stick were used to bind the xylem filter to the rubber hose and clear case to prevent leakage. The materials were locally available.

2.7 Plant Xylem Preparations

The xylems were acquired locally in Lunzuran, Zamboanga City. The branches consisted of plant xylem from mango (*Mangifera indica*), pomelo (*Citrus maxima*), and sampaloc (*Tamarindus indica*) trees, which were harvested as far from any connection to prevent dense xylems. The plant xylems were cut and shaped to their desired width and length, and then dry-preserved. To reduce sap, the xylem was boiled in non-aqueous solvents and dried thrice in an air fryer with 5-minute intervals.

2.8 Plant Xylem Filter Preparation

A clear case and hose adapter were acquired at CitiHardware in Boalan, Zamboanga City. A clear case where the dried plant xylem is placed; it is sealed with a glue gun to avoid leakage. A hose adapter is used as a channel to allow water to flow from the rubber pipe to the clear case, and a glue gun is used to seal the rubber pipe and clear case together to prevent leakage.

2.9 Water Filtration System Preparation

The water filter experimental setup consisted of plant xylem from mango (*Mangifera indica*), pomelo (*Citrus maxima*), and sampaloc (*Tamarindus indica*) trees. The water buckets were acquired at Wilcon Depot in Boalan, Zamboanga City. The feed water bucket is connected to the rubber pipe, and the glue gun is used to prevent leakage. The end of the rubber pipe is then attached to the clear case containing the xylem filter, and then it is connected to the treated water bucket. All connections are fixed with the use of a glue gun.

2.10 Experimental Procedure

The materials needed for the experimental procedure were purchased from local establishments and online stores. The components of the experimental setup were then assembled and managed. The xylem filter is prepared by cutting 4 centimeters in diameter and 1.27 centimeters in length, then attaching it to the end of the rubber pipe. A hose clamp and

epoxy hold the xylem filter and the rubber pipe together to avoid leakage. The other end of the rubber pipe is attached to the hose adapter, which is attached to the clear case, encasing the xylem filter inside. The end of the rubber pipe, exiting the clear case, is then attached to the feed water to convey the untreated water collected from the river of Barangay Lunzuran through the xylem filter. The xylem filter case end of the rubber pipe is then attached to a clear, sterilized water bucket, allowing the filtered water to drip down from the xylem filter. The clear water bucket and the xylem filter are sealed to prevent contaminants from entering the treated water. The treated water was collected from a faucet attached to the clear water bucket and poured into the water sampling bottles. The researcher employed a total of nine (9) trial runs to ensure the efficacy and effectiveness of the water filter setup: three (3) trial runs with mango tree (*Mangifera indica*), three (3) trial runs with pomelo tree (*Citrus maxima*), and three (3) trial run with sampaloc tree (*Tamarindus indica*). One (1) liter of treated water was collected for the physicochemical testing, and 100 mL of treated water was collected for the bacteriological testing.

The treated and untreated water samples were placed inside the ice box insulated cooler before it was tested for the thermotolerant coliform, arsenic, cadmium, lead, color, nitrate, pH level, turbidity, and total dissolved solids at Zamboanga City Medical Center – Laboratory. This procedure determined the efficacy and efficiency of the xylem filter.

2.11 Laboratory-scale Setup Trial Run

A trial run was conducted to determine the efficacy and efficiency of the setup design. The first trial run, water was poured into the feed water, allowing it flow through the rubber pipe and xylem filter case until it reached the clear water bucket to ensure that the rubber pipe and water buckets were working and had no leakage. In the second trial, untreated water was introduced into the experimental system and transported through a rubber pipe, utilizing the xylem of mango, pomelo, and sampaloc trees as filtration media. This process was conducted simultaneously across all three setups. The experiment measured the filtration flow rate and detention time required for water to pass through the media, with the purified water being collected in a clear bucket. In the third test, unfiltered water was brought into the experimental setup and transported through a rubber pipe, using the xylem of mango, pomelo, and sampaloc trees as a filtering medium. This process was conducted simultaneously across all three setups. The experiment measured the filtration flow rate and detention time required for water to pass through the media, with the purified water being collected in a clear bucket. The xylem of mango, pomelo, and sampaloc trees was used as the filtering medium in the fourth trial, in which untreated water was introduced into the experimental system and carried through a rubber pipe.

This process was conducted simultaneously across all three setups. The experiment measured the filtration flow rate and detention time required for water to pass through the media, with the purified water being collected in a clear bucket.

2.12 Laboratory Analysis

Approximately 1.1 liters of the collected water sample was sent to the ZCMC laboratory for the initial trial, where it was tested for thermotolerant coliform, arsenic, cadmium, lead, color, nitrate, pH level, turbidity, and total dissolved solids. After passing through the media and accounting for the detention time, 1.1 liters of treated effluent were collected and sent to the ZCMC laboratory to test the specified parameters and obtain the necessary data. This process was repeated for each experimental setup to complete three trials and to facilitate data comparison. The samples were stored in four (4) 1000 ml plastic bottles and four (4) 100 ml containers provided by the ZCMC laboratory. These were kept in a chilled, insulated icebox cooler to preserve the samples. The holding period from sample collection to laboratory testing was 3 hours.

With the water bucket indicators, the filtration rate was observed for each trial. The water buckets were sanitized before each trial run to ensure accurate results. The researcher adopted one (1) influent per trial run to ensure that the untreated water remains consistent across all experimental setups. Approximately 5 liters of point source water were poured into each experimental setup in each trial.

III. RESULT AND DISCUSSION

This chapter primarily discussed the effluent results from the xylems of the angiosperm species, which are the mango, pomelo, and sampaloc xylem. The results were obtained from the experiments conducted. It analyzes the results of the objectives of the study. The data gathered from the influent and effluent samples were examined to evaluate the performance of the filtration system and its compliance with water quality standards. The parameters such as pH level, turbidity, nitrate concentration, and heavy metal content were assessed and discussed. The chapter also interprets the trends, compares the results across multiple trials, and highlights significant insights while addressing the challenges encountered during the study. The Philippine National Standards for Drinking Water 2017 served as the basis for determining the quality of the treated water from the xylem filter.

TABLE 1. Influent and Effluent Water Sample Analysis

Parameters	Raw Water	Mango	Pomelo	Sampaloc
Total Coliform	Failed	Failed	Failed	Failed
Thermotolerant Coliform	Failed	Failed	Failed	Failed
Heterotrophic Plate Count	Failed	Failed	Failed	Failed
Arsenic	Passed	Passed	Passed	Passed
Cadmium	Passed	Passed	Passed	Passed
Lead	Passed	Passed	Passed	Passed
Nitrate	Passed	Passed	Passed	Passed
Color	Failed	Passed	Passed	Passed
Turbidity	Failed	Passed	Passed	Passed
pH	Passed	Passed	Passed	Passed
Total Dissolved Solids	Passed	Passed	Passed	Passed
Residual Chlorine	Passed	Passed	Passed	Passed

The results of the bacteriological and physicochemical water quality analysis conducted on the Lungsugan River. The analysis was carried out to assess the water's suitability for

drinking purposes by comparing the measured values of key parameters with the 2017 Philippine National Standards for Drinking Water (PNSDW) established by the Department of Health (DOH). The researcher observed that it showed mixed results after three (3) trials. The xylem filter demonstrated 0% removal efficacy for total coliform and heterotrophic plate count (HPC) bacteria, failing to meet drinking water standards. Although some reductions in thermotolerant coliforms/ E. coli were observed (ranging from ~9% to ~53% depending on the xylem type), effluent levels still exceeded drinking water standards. The xylem filter effectively removed all detectable colors, meeting drinking water standards. Turbidity was significantly reduced (around 80-83%), even though influent turbidity already met drinking water standards. The xylem filter had no measurable impact on arsenic, lead, or nitrate levels. However, influent levels of these parameters were already within acceptable limits. The xylem filter impact on total dissolved solids (TDS) was inconsistent, with some trials showing slight increases in TDS (negative removal efficacy).

TABLE 2. Removal Efficiency

Parameters	Mango	Pomelo	Sampaloc
Total Coliform	0%	0%	0%
Thermotolerant Coliform	51.9%	19.0%	28.9%
Heterotrophic Plate Count	0%	0%	0%
Arsenic	0%	0%	0%
Cadmium	-600%	0%	-50%
Lead	0%	0%	0%
Nitrate	0%	0%	0%
Color	100%	100%	100%
Turbidity	81.29%	82.05%	81.95%
pH	-	-	-
Total Dissolved Solids	-8.25%	-7.39%	-10.12%
Residual Chlorine	0%	0%	0%

In summary, the study found that while the xylem filters were effective in improving water clarity, they were not successful in removing bacterial contamination. The filters showed only a slight reduction in thermotolerant coliforms. Furthermore, the study revealed an increase in cadmium levels in the effluent from both the mango and sampaloc xylem, indicating a potential species-specific vulnerability to cadmium uptake due to weaker casparian strips in the plant xylem.

IV. CONCLUSION

This chapter presents the conclusions and recommendations from the study conducted on mango, pomelo, and sampaloc tree xylem within the Lunsungan River as an alternative water filter system. The findings and discussions presented in the preceding chapters form the basis for the insights discussed herein. Additionally, this chapter discusses the theoretical and practical consequences of the present work, as well as the recommendations for future research.

The laboratory results of the bacteriological analysis of the Lunsungan River reveal that the water quality falls short of the necessary drinking water standards. Total coliform levels remained consistently high with >200.5 MPN/100 mL, the

thermotolerant coliform levels ranging from 94.5 to > 200.5 MPN/100 mL, and the heterotrophic plate count levels remained consistently high with > 6,500 CFU/mL in both influent and effluent throughout all trials. Meanwhile, the physico-chemical testing results indicate that the water quality met the required drinking water standards. Arsenic, lead, nitrate, and residual chlorine levels consistently remained well below the required thresholds. Cadmium, color, turbidity, pH, and total dissolved solids, while showing some variation, also fell within acceptable limits. This suggests that while some of the physico-chemical parameters are within the acceptable limits, the water is not safe for consumption due to the presence of harmful bacteriological contaminants.

Based on the findings, the effluent from xylem filters constructed using mango (*Mangifera indica*), pomelo (*Citrus maxima*), and sampaloc (*Tamarindus indica*) trees was evaluated and assessed with the 2017 Philippine National Drinking Water Standards. It was revealed that the three xylem filters failed to meet the standards for total coliform which has the result of >200.5 MPN/100mL, thermotolerant coliform with the results ranging from 94.5 – 165.2 MPN/mL but still failed to meet the standards and heterotrophic plate count which has the result of >6,500 CFU/mL across all three trials. On the other hand, the effluent from xylem filters constructed using mango (*Mangifera indica*), pomelo (*Citrus maxima*), and sampaloc (*Tamarindus indica*) trees, assessed with the 2017 Philippine National Drinking Water Standards revealed that the three xylem filters passed the standards for arsenic with the results of <0.002 mg/L, cadmium with the results ranging from <0.0002 – 0.0003 mg/L, lead with the results of <0.002 mg/L, nitrate with the results of <0.9 mg/L, color with the results of no color, turbidity with the results ranging from 0.82 – 0.87, pH with the results ranging from 6.9 – 8.4, total dissolved solids with the results ranging from 228 – 304 mg/L and residual chlorine with the results of <0.01 mg/L across all three trials. The cadmium levels showed an increase in the effluent of the mango and sampaloc xylems, which indicates that the Casparian strips in these xylems are weaker than those in the pomelo xylem. The location of the trees where the xylems were collected is within a 5-meter radius, which suggests that there was no significant variation in environmental factors, such as soil pH and moisture, that could have contributed to the observed differences in cadmium uptake.

The study found that comparing the effluent results from the use of mango (*Mangifera indica*), pomelo (*Citrus maxima*), and sampaloc (*Tamarindus indica*) tree xylem filters to the Philippine National Standards for Drinking Water (PNSDW) 2017. It showed that the bacteriological parameters of total coliform, thermotolerant coliform, and heterotrophic plate count levels, and the physico-chemical parameters, particularly the cadmium levels, were not safe for human consumption. This is a significant finding as it indicates potential limitations in the effectiveness of these xylem filters in removing bacteriological contaminants, and particularly heavy metals, from water sources. Therefore, the treated water is deemed unsafe for human consumption.

V. APPENDICES



Figure 1. Mango Xylem Filter



Figure 2. Pomelo Xylem Filter



Figure 3. Sampaloc Xylem Filter

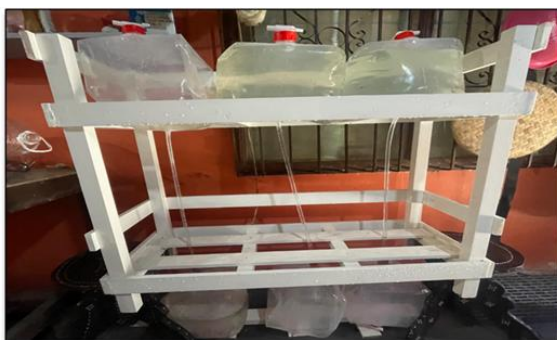


Figure 4. Actual Water Filter Experimental Setup



Figure 5. Influent and Effluent Water Collected for Physico-chemical Analysis



Figure 6. Influent and Effluent Water Collected for Bacteriological Analysis

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