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Research Article

GREYWATER RECYCLING THROUGH BAMBOO-BASED PURIFICATION SYSTEM

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ABSTRACT

Greywater recycling through a bamboo-based purification system was conducted in one of the areas in the Philippines. The chemical characteristics of greywater, such as BOD, COD, TSS, TDS, pH, nitrate, and phosphorus, before and after treatment by bamboo plants, were measured and compared to the Department of Environment and Natural Resources (DENR) standards. Results showed that the growth of bamboo had increased in terms of height, weight, and length of roots after the application of greywater. The chemical characteristics of greywater applied to bamboo plants decreased nitrate content from 11.04 mg/L to 4 mg/L, phosphorus from 1.9 ppm to 0.08 ppm, COD from 2465 mg/L to 191.50 mg/L, and TSS from 170 mg/L to 93.08 mg/L. The following chemical characteristics of greywater differed significantly from the DENR standards after application to bamboo plants: Nitrates ($p = 0.00$), Phosphorus ($p = 0.00$), TSS ($p = 0.00$), and Fat content ($p = 0.00$). Bamboo plants are potential media or materials to use for greywater purification. The chemical characteristics of greywater after application to bamboo plants were significantly improved and met DENR standards.

Keywords: Bamboo; Chemical Characteristics; Greywater recycling; Purification System.

INTRODUCTION

Environmental and ecological problems are major global concerns, often arising from excessive demands on scarce natural resources and the resultant pollution caused by over-development and poverty. Common water supplies face contamination due to the improper disposal of waste, compounding these issues. In the Philippines, the severity of the problem is evident, with up to 58% of groundwater being contaminated by E. Coli, requiring treatment (Philippine Environment Monitor, 2003). The remaining water sources, primarily surface water, are vulnerable to contamination due to inadequate sanitation and exposure to the elements. Therefore, it is imperative to implement comprehensive water demand and supply management strategies.

In Cagayan de Oro, water supply predominantly relies on groundwater sources. The province is blessed with abundant natural water resources, including 48 rivers (with a combined discharge capacity of 42,600.71 liters per second), 60 creeks, 38 springs (with a daily output of 48,432 cubic meters), and two natural lakes. However, the region faces significant challenges, including insufficient water supply and waste treatment facilities (Census 2000). The rapid population growth and increasing water demand add stress to water resources, sanitation, and wastewater disposal systems, leading to a gradual reduction in water availability. Consequently, it is crucial to minimize improper wastewater disposal, enhance water use efficiency through reuse options, and establish an economic framework that prioritizes resource conservation and protection over destruction.

Gupta *et al.,* (2004) project that recyclable wastewater will account for 15% of the total water requirement by 2050. The Philippine Clean Water Act of 2004 defines water quality based on various characteristics, including physical, chemical, biological, bacteriological, and radiological properties, which determine the acceptability and classification of water resources for beneficial use. While bamboo has been identified as an alternative medium for treating greywater and wastewater, there is a scarcity of published literature and research at the local level. Consequently, this study aimed to evaluate the growth of bamboo in terms of height, weight, and root length after the application of greywater. Additionally, it seeks to measure the chemical characteristics of greywater, encompassing parameters such as nitrates, phosphorus, potassium, COD, pH, fat content, TSS, and BOD, both before and after application to bamboo plants. The study also aimed to determine whether the chemical characteristics of greywater conform to DENR standards after being applied to bamboo plants.

METHODOLOGY

Site Selection

The study was conducted in SEARSOLIN, Manresa Farm, Cagayan de Oro City. It is an experimental area of the College of Agriculture, Xavier University, and at the same time a demonstration farm for small farmers. Among the establishments or institutions present in Manresa, the Southeast Asia Rural Social Leadership Institute (SEARSOLIN) is one of the major producers of greywater in the said area since it is a training center with dormitories and they cater to regular customers. It produces an estimated of 400 liters per day of greywater.

The greywater coming from the canteen of SEARSOLIN was impounded in one area through gravity flow and pipes in carrying through the water. Beds lined with an impermeable liner and filled with graded medium with bamboo plants as the treatment medium.

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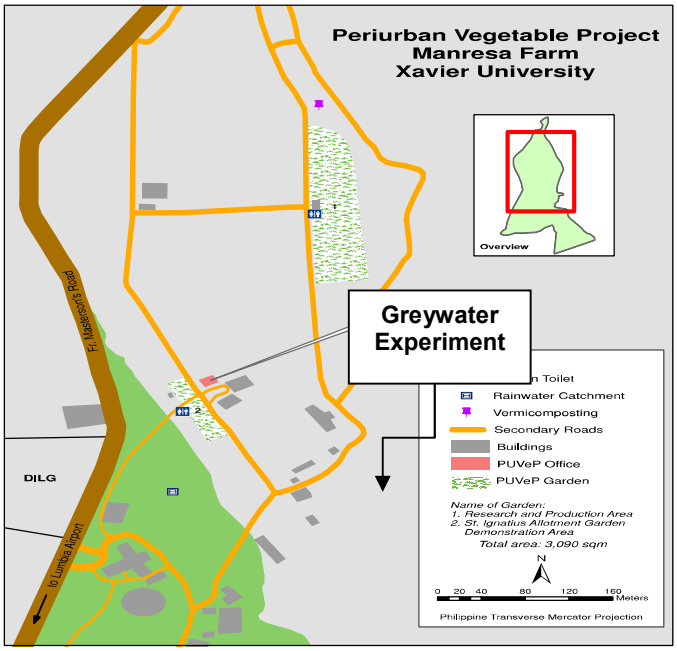

Figure 1: Location Map of the Greywater Experiment

Sampling Design

The study used the randomized block design method wherein there was a blocking or grouping of subjects with similar characteristics into treatment subgroups. There were four treatments with three replications per treatment and one control variable. Several steps were done in the whole experimental process. First, prepare 18 plastic pails/buckets (520 cm or 22 inches in length) with the same size and media (40:60 ratio-soil/gravel). Second, transplant 2-year-old bamboo plants to the 12 plastic pots; the remaining pots were used for the control variable. Each pot was watered with greywater 3x a week. Third, collect the treated greywater after 1 month and bring the samples to the laboratory for chemical analysis. Finally, compare the results before and after the application of greywater bamboo plants.The greywater samples were collected from SEARSONLIN's sink (training center).

Data Gathering

From the Bamboo plant set-up: there were twelve (12) samples collected from the different treatments and six (6) samples from the controlled variable after one month of application. All the samples were analyzed its chemical characteristics at the Department of Science and Technology (DOST Region X); F.A.S.T Laboratories and Food Technology Center, Xavier University. The study considered the following chemical characteristics namely: Nitrates, Phosphorous, Potassium, Fat, pH, BOD, COD, and TSS, which were based on the Department of Environment and Natural Resources (DENR) Water Quality Guidelines and General Effluent Standards.

Statistical Analysis

The study used Microsoft Excel for data tabulation, cleaning of errors, and graph presentations. The Excel Stat Software was used for the statistical analysis. The study further used the Wilcoxon Signed Rank Test (Nonparametric test) for the test of significance of the results.

RESULTS AND DISCUSSION

Growth of Bamboo before and after applied with greywater

The results presented in Table 1 demonstrate the positive impact of applying greywater on the growth of bamboo plants. The height, weight, and length of roots all increased after the application of greywater. These findings are consistent with previous research by Del Porto (2006), who highlighted that wastewater containing nutrients, organics, and a substantial volume of water can serve as an ideal and valuable resource for plant growth.

However, it is essential to consider the potential adverse effects of greywater reuse on groundwater and ensure the effective utilization of the greywater system. As recommended by the World Health Organization (WHO, 2006), users must analyze and study the specific nutrient requirements of the plants and soil to minimize any negative impacts. This analysis will help optimize the nutrient composition of the greywater and ensure its compatibility with plant growth.

Additionally, it is important to note that greywater should be applied to well-established plants rather than seedlings or young plants. This precaution is necessary because seedlings and young plants are more sensitive to impurities present in the greywater. By restricting greywater use to mature plants, the potential risks associated with impurities can be minimized, while still benefiting from the resource efficiency offered by greywater reuse.

Table 1 provides quantitative data on the growth parameters of bamboo plants before and after the application of greywater. The height of the bamboo increased from 37.35 cm to 41.20 cm, representing a noticeable growth enhancement. Similarly, the weight of the plants increased significantly, rising from 1.84 kg to 6.52 kg. Moreover, the length of the roots exhibited substantial growth, increasing from 62.83 cm to 104.25 cm. These findings indicate that the application of greywater positively influences the growth and development of bamboo plants.

Table 1 Growth of Bamboo in terms of height, weight, and length of roots before and after applied with greywater

Growth Parameters	Before application	After application
Height (cm)	37.35	41.20
Weight (kl)	1.84	6.52
Length of roots (cm)	62.83	104.25

Chemical Characteristics of greywater before and after application to bamboo plants

The chemical characteristics of greywater, specifically nitrates, phosphorous, potassium, chemical oxygen demand (COD), pH, fat content, total suspended solids (TSS), and biochemical oxygen demand (BOD), were evaluated before and after application to bamboo plants. The results presented in Table 2 demonstrate the changes in these characteristics after greywater application.

After the application of greywater to bamboo plants, significant reductions were observed in the levels of nitrates, phosphorous, potassium, COD, pH, fat content, and TSS. The nitrates content decreased from 11.04 mg/L to 4 mg/L, representing a reduction of 7.04 mg/L. Similarly, phosphorous levels decreased from 1.9 ppm to 0.08 ppm, indicating a decrease of 1.82 ppm. The potassium content decreased from 19 ppm to 16.42 ppm, reflecting a reduction of 2.58 ppm. Furthermore, the COD decreased from 2465 mg/L to 191.50 mg/L, exhibiting a substantial reduction of 2,273.50 mg/L. The pH decreased from 6.3 to 6.08, demonstrating a decrease of 0.22. Additionally, the fat content decreased from 0.24% to 0.4%, resulting in a reduction of 0.2%. Moreover, the TSS decreased from 170 mg/L to 93.08 mg/L, indicating a reduction of 76.92 mg/L. However, the BOD content did not change significantly, remaining relatively stable throughout the application process.

These findings highlight the ability of bamboo plants to positively impact the chemical characteristics of greywater. Bamboo's complex root system acts as a natural water filter, effectively removing nutrients and harmful substances like heavy metals from the water, thus preventing their entry into the food chain (Kitil Farm Report, 2013). The reduction observed in nitrates, phosphorous, potassium, COD, pH, fat content, and TSS after greywater application suggests that bamboo plants effectively utilize and absorb these substances, contributing to their remediation. The decrease in these chemical parameters indicates that the greywater treated by bamboo plants becomes less polluted and potentially safer for reuse or release into the environment.

Furthermore, bamboo offers several additional environmental benefits. Its dense and sturdy root system allows for rapid growth and resilience to environmental stresses. Additionally, bamboo has a high heating value, making it a valuable biomass energy source. These attributes further enhance the environmental value of bamboo and reinforce its potential as a sustainable solution for greywater treatment and overall environmental management.

Table 2 The chemical characteristics of greywater such as Nitrate, Phosphorous, Potassium, COD, pH, Fat content, TSS and BOD before and after application to bamboo plants.

Chemical characteristics	Before application $\bar{x}$	After application $\bar{x}$	Remarks
Nitrates (mg/L)	11.04	4	Decreased by 7.04 mg/L
Phosphorous (ppm)	1.9	0.08	Decreased by 1.82 ppm
Potassium (ppm)	19	16.42	Decreased by 2.58 ppm
Chemical Oxygen Demand (mg/L)	2465	191.50	Decreased by 2,273.50 mg/L
pH	6.3	6.08	Decreased by 0.22
Fat (%)	0.24	0.4	Decreased by 0.2%
Total Suspended Solids (mg/L)	170	93.08	Decreased by 76.92 mg/L
Biochemical oxygen demand (mg/L)	325.5	579.50	Increased by 254 mg/L

Chemical Characteristics of greywater after applied to Bamboo plants

Table 3 presents the results of the Wilcoxon Signed Rank Test, which determined whether the chemical characteristics of greywater after application to bamboo plants were within the standards set by the Department of Environment and Natural Resources (DENR). The findings reveal that several chemical parameters, namely nitrates, phosphorous, total suspended solids (TSS), and fat content, were significantly improved and met the DENR standards after application to bamboo plants.

The measured values of nitrates, phosphorous, TSS, and fat content after greywater application were 4 mg/L, 0.08 ppm, 93.08 mg/L, and 0.4%, respectively. These values were compared to the DENR standards of 10 mg/L for nitrates, 0.4 ppm for phosphorous, 150 mg/L for TSS, and 5% for fat content. The statistical analysis using the Wilcoxon Signed Rank Test revealed highly significant p-values (p=0.00) for all these parameters, indicating that the observed improvements were statistically significant.

The results suggest that bamboo plants have a higher potential for purifying greywater by reducing the levels of nitrates, phosphorous, TSS, and fat content. This aligns with previous research funded by the European Commission, which highlights the effectiveness of bamboo in phytoremediation water. Phytoremediation processes, such as the one facilitated by bamboo, utilize natural materials to absorb and break down pollutants, distinguishing them from processes that merely capture contaminants and dispose of them elsewhere.

While the chemical oxygen demand (COD), pH, and biochemical oxygen demand (BOD) did not meet the DENR standards after greywater application, it is important to note that bamboo plants showed significant improvements in nitrates, phosphorous, TSS, and fat content. The COD and BOD values after application were 191.50 mg/L and 579.50 mg/L, respectively, indicating a higher concentration compared to the DENR standards of 100 mg/L for COD and 150 mg/L for BOD. The pH value after application was 6.08, falling within the acceptable range of 6.0-9.0, although it did not reach the ideal neutral value of 7.0.

The results of this study suggest that bamboo plants possess the ability to effectively reduce specific pollutants in greywater and bring them within the acceptable limits set by regulatory standards. This highlights the potential of bamboo as a natural and sustainable solution for greywater treatment and purification. Further research is warranted to investigate the long-term effectiveness of bamboo in remediation processes and to explore strategies to optimize its performance in achieving overall water quality objectives.

Table 3 Determine whether the chemical characteristics of greywater are within DENR standards after applied to Bamboo plants using Wilcoxon Signed Rank Test.

Chemical characteristics	DENR standard	Measured value after application	p value
Nitrates (mg/L)	10	4	.00
Phosphorous (ppm)	0.4	0.08	.00
Potassium (ppm)		16.42	
Chemical Oxygen Demand (mg/L)	100	191.50	1.00
pH	6.0-9.0	6.08	.56
Fat (%)	5	0.4	.00
Total Suspended Solids (mg/L)	150	93.08	.00
Biochemical oxygen demand (mg/L)	150	579.50	.75

CONCLUSION AND RECOMMENDATION

Greywater reuse has a long history and continues to be practiced in various communities. In this study, it was observed that the application of greywater contributed to the growth of bamboo plants in terms of height, weight, and length. However, it is crucial to implement proper treatment measures to minimize potential adverse effects on both plant and human health before utilizing greywater as recycled water.

The results of the experiment revealed significant improvements in the chemical characteristics of greywater after its application to bamboo plants, which were found to be within the standards set by the Department of Environment and Natural Resources (DENR). This suggests that bamboo plants can effectively purify greywater and make it suitable for reuse.

Bamboo plants demonstrate great potential as a medium for wetland construction and an alternative material for greywater purification. Considering the efficiency of the studied system, it is highly recommended to replicate the experiment on a larger scale and establish a full-scale wetland utilizing bamboo plants as the filtration medium. This would provide valuable insights into the practical application of bamboo in large-scale greywater treatment systems and further enhance the understanding of its potential as a sustainable solution for water purification.

This study highlights the importance of greywater treatment to ensure the safe and beneficial reuse of this valuable resource. The utilization of bamboo plants in greywater purification shows promise for achieving improved water quality and addressing water scarcity challenges. Continued research and implementation of such systems are crucial for advancing sustainable water management practices and promoting environmental stewardship.

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