19th International Conference on Environmental Science and Technology

Kos, Greece, 3 to 6 September 2025

Investigating the Potential of Phytoremediation-assisted Treatment of Rainwater for Domestic Use using Selected Agro-wastes as Filter Media

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Abstract The Bicol Region is one of the most exposed areas to natural disasters in the Philippines. It is economically reliant on agriculture, with coconut and rice among the important crops being produced. This study looks into the potential of utilizing locally available agro-waste materials as sustainable and cost-effective solutions to the artificial scarcity of good quality water from abundant rainwater and stormwater run-off for many disadvantaged communities in the region. Cocopeat (CP) and carbonized rice hull (CRH) were studied as alternative adsorptive materials to sand (S) in the preliminary treatment of rainwater via filtration. Vetiver grass (*Chrysopogon zizanioides*) and reeds (*Phragmites karka*) were planted onto cocopeat (CP + Phy) to enhance its filtering performance. The treatment efficacy of the filter materials was determined by comparing the pH, total dissolved solids (TDS), temperature, oxidation reduction potential (ORP), resistivity and salinity of rainwater before and after filtration. Analysis of variance (ANOVA) was used to compare the performance of the filter media tested. The treatment performance of cocopeat is comparable to sand in improving the quality of the tested rainwater samples. Further improvement in the treatment efficiency of cocopeat was observed on some water quality parameters when phytoremediating plants were added.
Keywords: rainwater, stormwater, harvesting, filtration, treatment

1. Introduction

Rainwater harvesting refers to the principle and the technology of collecting and using precipitation from a small catchment area, usually immediately upon the time that the precipitation has fallen on the ground. Meanwhile, a slow sand filter is basically a large tank containing a sand bed. Water is introduced at the top and trickles down through the sand (acting as filter material) to the underdrains and goes to a storage tank. These two methods are some of the most basic and oldest means by which water is made accessible in a safe and sanitary manner for domestic consumption. Phytoremediation on the other hand uses plants to remove contaminants from water via pollutant uptake, degradation and immobilization (Allende et al., 2014; Jeevanantham et al., 2019).

Agro-based granular materials can be used as alternatives to traditional filter media types (Ahmad, 2023; Ali et al., 2022; Noor & Khan, 2023) in improving the quality of raw rainwater and stormwater. They are commonly considered as agricultural by-products and are locally abundant, thus, are cheaper and more sensible options under ideal conditions. Combining phytoremediation with filtration using agro-based media will leverage the natural abilities of plants to purify water while making use of environment friendly and cost-effective materials.

2. Methodology

Treatment modules were fabricated from 200 liter high density polyethylene (HDPE) cylindrical barrels fitted with pipes and screens to contain granular materials and effect filtration as raw rainwater or stormwater passes through the filter bed. Sand (S), carbonized ricehull (CRH), and cocopeat (CP) were used as filter media. An additional set-up containing cocopeat planted with phytoremediationg plants (CP +Phy) was prepared to measure the effect of phytoremediation. To measure the performance of the filter media in treating the rainwater, physical water quality parameters were recorded by obtaining grab samples of the rainwater from the raw rainwater holding tank (before treatment) and at the discharge pipe of the modules (after treatment). The samples were tested for pH, total dissolve solids (TDS), temperature, oxidation reduction potential (ORP), resistivity, and salinity using the electrochemical method via a handheld multi-parameter water quality meter.

To compute the treatment efficiency, the following equation is used:

$$Efficiency = \left[\frac{(WQ_{before} - WQ_{after})}{WQ_{before}}\right] \times 100\%$$

Where:

WQ_{before} – the water quality parameter (pH, TDS, etc.) value entering the module

WQ_{after} – the water quality parameter value exiting the module

To evaluate the effect of phytoremediation, the performance of phytoremediation modules is compared to modules with cocopeat as filter media since the phytoremediating modules have cocopeat as growth medium for the phytoremediating plants. In this case, the modules with cocopeat as filter medium are the control samples, and any indication of variance between the two will be an indication of the effect of phytoremediation in the filtration system. Analysis of Variance (ANOVA) is used to check for significant differences in the performance of the different filter media types with four replicates for each type.

3. Results and discussion

The performance of the different filter media in improving the quality of rainwater is presented in Table 1. Except for CRH, all the filter media tested were observed to have a statistically significant effect in reducing the pH, TDS, temperature and salinity. There was no observed change in the salinity value of the rainwater when filtered using CRH. All filter media likewise, significantly increased the resistivity and ORP values of the filtered rainwater.

Table 1. % efficiency in water quality after filtration

Parameter	Medium			
	S	CP	CRH	CP + Phy
pH ↓	11.0	19.2	5.8	23.6
TDS ↓	28.7	45.7	7.1	41.5
Temperature ↓	4.3	3.2	2.4	8.1
ORP ↑	43.9	121.1	39.1	105.4
Resistivity ↑	41.7	84.9	7.6	72.1
Salinity ↓	33.3	50.0	0.0	33.3

n.b. - ↓ indicates reduction; ↑ indicates increase

The effect of phytoremediation on the treatment performance of cocopeat is shown in Table 2. A significant difference can be observed in the performance of the phytoremediation modules and those that contain cocopeat as filter medium on pH, temperature and ORP.

Table 2. Phytoremediation effect on treatment performance

Parameter	Module/Medium		Effect
	CP	CP + Phy	
pH ↓	19.2	23.6	**
TDS ↓	45.7	41.5	*
Temperature ↓	3.2	8.1	**
ORP ↑	121.1	105.4	**
Resistivity ↑	84.9	72.1	*
Salinity ↓	50.0	33.3	*

n.b. - * no significant effect; ** with significant effect

This means that the module performance in reducing pH and temperature is enhanced when phytoremediation is employed; while in the case of ORP, the module performance is reduced in increasing ORP. No significant difference can be observed on TDS, resistivity and salinity.

In summary, except for CRH, all the filter media tested have positive effects in improving the physical properties of rainwater. Over-all, cocopeat and sand have very good treatment potential in improving physical water quality to potable standards. Phytoremediation improves pH and temperature treatment efficiency but reduces ORP enhancement.

4. Conclusions

In terms of the physical water quality parameters tested, the modules with sand, cocopeat, cocopeat with phytoremediating plants and carbonized rice hull as filter media have shown sufficient efficacy in treating rainwater to attain potable water quality. The use of phytoremediating plants resulted in the improvement of treatment efficacy in several physical water quality parameters, except ORP where a decline in efficacy was observed. Although an improvement in performance was detected, it should be noted that other relevant parameters such as microbiological characteristics have not been included in this investigation to warrant a conclusive statement as to the sufficiency of filtration plus phytoremediation to treat rainwater to the acceptable potability level.

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