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Backwashed Slow Sand Filter Using Anthracite Coal as a Filtering Medium for Application in Isolated Rural Communities

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Highlights:

- The backwashed slow sand filter filled with anthracite coal showed potential for use in terms of treated water quality.
- Head loss was concentrated in the first few centimeters of the filter medium.
- The depletion of dissolved oxygen throughout the filter medium indicates its maturation.

Keywords: isolated rural communities; backwashed slow sand filtration; anthracite coal.

INTRODUCTION

The significant demand for water in both quantity and quality is one of today's major challenges, according to the World Health Organization (WHO, 2024). In Brazil, many regions, especially isolated rural communities, still lack a potable water supply system, resorting to alternative sources without proper treatment, which exposes them to health risks (EMBRAPA, 2020).

Slow sand filtration is an ancient technique that has been applied globally in public water supply systems (Nakamoto et al., 2014). This technique is efficient not only because of its simple construction and maintenance but also due to the quality of treated water and the absence of chemical additives during its operation (Gimbiel et al., 2006). Recently, backwashed slow sand filtration (BSSF) has also garnered the interest of researchers due to its efficiency in water purification through chemical, physical, or biological retention of impurities (Souza et al., 2014).

This study aimed to evaluate a BSSF system using anthracite coal as the filter medium. The goal was to optimize its operation due to its unique physical characteristics, which allow for a 37% reduction in the volume of water needed for backwashing and a shorter filtration recovery time compared to sand-filled BSSF (30% lower). A pilot system was constructed and operated for potential future application in isolated rural communities, and hydraulic and water quality parameters were monitored.

METHODOLOGY

The study was conducted in the state of Rio Grande do Sul, at the Federal University of Santa Maria - Frederico Westphalen campus. The backwashed slow sand filtration (BSSF) system was designed and developed following the guidelines of the National Health Foundation (FUNASA, 2019) and technical guidance from Seckler (2017).

The BSSF system was constructed using 100 mm diameter PVC with a height of 2.0 meters. The filter medium (anthracite coal) had a thickness of 40 cm, supported by a 10 cm gravel layer. Piezometers were installed at different depths along the filter medium to monitor head loss. The system also included a flow dosing trough for raw water intake, which was measured daily using the volumetric method. The anthracite coal filter medium had an effective diameter (d10) of 0.3 mm and a uniformity coefficient (CU) of 1.7. Figure 1 shows a schematic of the prototype developed in this study.

The raw water used by the system was sourced from a reservoir. The system initially operated for 12 days, completing two filtrations run with continuous operation, allowing for daily monitoring of water quality parameters such as turbidity, apparent color, true color, pH, temperature, electrical conductivity, and dissolved oxygen, as well as hydraulic parameters including flow rate and head loss. The selected water quality parameters followed the guidelines of the American Public Health Association (APHA, 2017).

RESULTS AND CONCLUSIONS

After 12 days of operation, completing two filtrations run, and still during the maturation phase of the filter medium, the backwashed slow sand filtration (BSSF) system showed 56.5% turbidity removal and 72.5% true color removal for the selected water quality parameters. These results are similar to those observed by Lunardi (2021), positively highlighting the effectiveness of the filter medium in BSSF. The depletion of dissolved oxygen throughout the filter medium indicates its initial maturation phase (Poncio, 2023). Preliminary results of the water quality parameters are shown in Table 1.

Table 1: Performance of the filtration system by water quality parameter.

FILTR. RUN	SAMPLE TYPE	Turbidit (NTU) (M± SD)	App. Color (Hu) (M±DP	True color (Hu) (M±SD)	pH (M±SD)	Temp. (°C) (M±SD)	E.C. (µm/cm) (M±SD)	D.O. (mg/L) (M±SD)
1	R.W.	4.18	71.93	93.67	6.64	21.83	115.27	6,51
	F.W.	1.41	48.80	21.33	6.46	20.66	118.98	7,12
2	R.W.	5.30	107.90	81.83	6.67	21.42	469.88	6,31
	F.W.	2.71	79.90	27.00	6.62	20.83	470.46	5,69
GLOBAL REMOVAL (%)		56,5	28.4	72.5	0	0	0	0.1

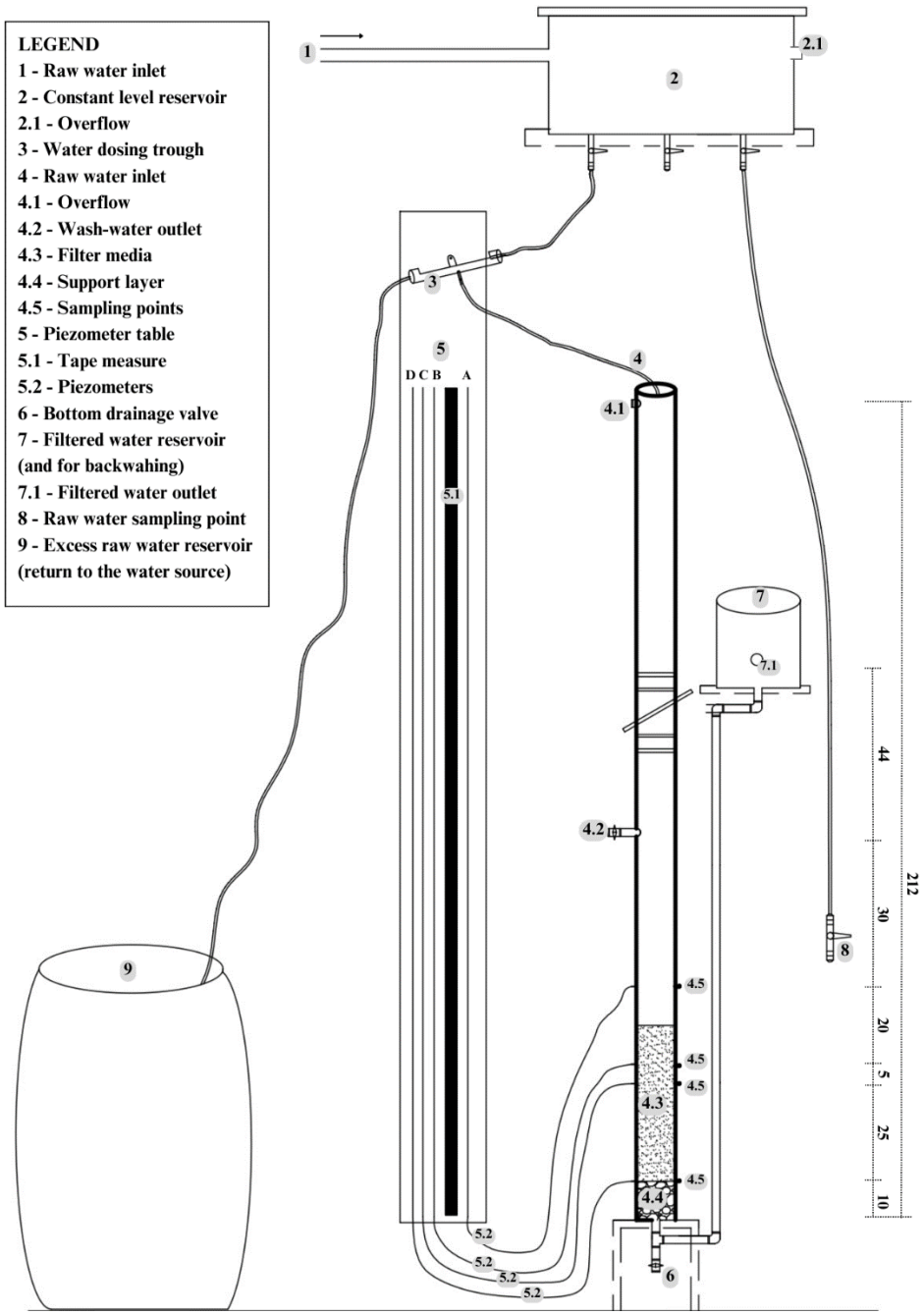
Note: R.W. - Raw Water; F.W. - Filtered Water; M – Mean, Filtr. Run – Filtration Run, App. Color – Apparent Color, Temp. – Temperature, E.C. – Electrical Conductivity, D.O. – Dissolved Oxygen.

Head loss was predominantly observed in the upper layer of the filter medium (0-10 cm), suggesting this layer may be responsible for biological clogging, which is crucial in the slow sand filtration process. These findings are similar to those observed by Poncio (2023) using the same filter medium and raw water source.

Although the results are still preliminary, the backwashable slow sand filtration (BSSF) system using anthracite coal shows potential for use in isolated rural communities, with water quality results comparable to those of sand-filled slow sand filtration systems. In terms of head loss, the filter medium performed within the expected limits for its particle size distribution. Thus, the BSSF system filled with anthracite coal demonstrates its capability to produce water in both quantity and quality comparable to

its sand-filled counterpart, with the added advantage of reducing the volume of water needed for backwashing by 37% and the time required to resume filtered water production after cleaning by 30%.

Figure 1: Layout of the backwashed slow sand filtration system.



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