Nature's Filter: Improving Water Quality with Coconut and Rice Husk Bio-Char

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ABSTRACT

The quality of well water is poor along the riverbanks because the river is polluted with solid and liquid waste. The effects of consuming low-quality well water include decreased bone density, tooth decay, anemia, and kidney disorders. The purpose of this study is to examine the effectiveness of coconut shells and rice husks in improving well water quality. This research design is a pretest-posttest with a control group, water samples from dug wells along the riverbank in Cimahi City. This study used three sample groups: 9 samples were given coconut shells, 9 samples were given rice husks, and 9 samples were in the control group. Each sample group used 10 liters of well water. Turbidity, TDS, TSS, Fe, Mn, pH, DO levels were measured before and after the intervention. Data analysis using dependent t-tests and ANOVA tests. The results of the study on turbidity, TDS, TSS, Mn, pH, and DO of well water before and after filtration using coconut shell charcoal and rice husks showed significant differences ($p<0.05$), while Fe did not show significant differences ($p>0.05$). There were significant differences in turbidity, TDS, TSS, pH, and DO between the coconut charcoal group and the rice husk group ($p< 0.05$), while there were no significant differences in Fe and Mn between the coconut charcoal group and the rice husk group ($p>0.05$). The results of this study indicate that coconut shell charcoal is more effective at improving well water quality than rice husk charcoal.

Keywords: Coconut shells, Fe, Rice husks, TSS, Turbidity

Introduction

Groundwater is a primary need for the community, If water needs are not adequately met, it will have an impact on public health (Xie et al., 2023). Public health is influenced by the availability of clean and safe drinking water. Communities that do not receive clean water services from the Local Water Supply Utility use groundwater (well water) to meet their daily needs. The quality of dug wells based on physicochemical parameters is generally poor, especially in industrial areas, flood-prone areas, and riverbanks contaminated with liquid waste (Uwimpaye et al., 2025).

The quality of groundwater used by the community falls short of healthy drinking water standards; in fact, in several regions, the groundwater is unfit for consumption. According to the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017, clean water quality is mandated to meet specific standards encompassing physical, chemical, and microbiological criteria. Water characteristics—such as color, temperature, acidity, pH levels, sulfate and chloride content, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and alkalinity—are considered physicochemical parameters (Jaafar et al., 2020).

Cimahi is one of the industrial hubs located in West Java Province. The city is divided into three districts: North Cimahi, Central Cimahi, and South Cimahi. Central Cimahi is designated for trade, services, education, and administration, while North Cimahi focuses on education, public services, and administration. Meanwhile, South Cimahi is designated for industry, education, and public services. The industrial sector in South Cimahi encompasses small, medium, large-scale, and home industries. This high concentration of industry has had an adverse impact on the environment, particularly affecting the quality of river water and dug wells.

The long-term effects of poor water quality lead to decreased bone density, dental damage, anemia, and renal impairment (Costacurta et al., 2022). These effects result from water contamination with hazardous heavy metals that accumulate in the kidneys. This issue warrants serious concern from communities living along riverbanks to prevent the negative impacts of low-quality well water. To address this problem, novel and sustainable methods for improving water quality are being explored. A promising approach involving the use of natural materials, such as coconut shells and rice husks, has been proven to enhance the physical and chemical standards of water (Marlinae, Biyatmoko, 2024).

Coconut shells are abundant agricultural by-products widely recognized for their high porosity and contaminant absorption capabilities. They contain natural activated carbon, which is effective in removing impurities—including organic compounds, heavy metals, and pathogens—from water. Research indicates that coconut shells function as an effective adsorbent for heavy metals in aqueous solutions with low metal concentrations (Minh et al., 2023). Rice husk is an agricultural waste generated during the rice milling process, possessing natural adsorption properties and a high silica content, which makes it suitable for water treatment applications. It can remove various pollutants, including heavy metals and organic compounds, through physical and chemical processes such as adsorption and catalysis (Okoro et al., 2022).

Coconut shells and rice husks are local biological waste materials that can be processed into activated carbon, such as biochar and ash. This activated carbon can adsorb specific gases and chemical compounds due to its selective adsorption properties, which are determined by pore size and surface area. Activated carbon possesses a significant adsorption capacity, ranging from 25% to 1000% of its weight, making it highly effective in reducing organic contaminants and synthetic organic particles, as well as inorganic pollutants such as radon, mercury, and other hazardous metals (Sabzehmeidani et al., 2021). The combination of coconut shells and rice husks in water treatment systems provides a viable solution for improving the quality of dug well water in riverbank areas contaminated by liquid waste. The complementary properties of these natural materials can be leveraged to enhance water quality, increase filtration efficiency, and minimize environmental impacts (Vieira et al., 2024).

The utilization of local resources encourages community engagement in addressing water-related challenges. One strategy to enhance physical standards—namely Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Turbidity, and Total Suspended Solids (TSS)—as well as chemical standards, including acidity levels (pH), Iron (Fe), and Manganese (Mn) in riverbank dug wells, is the utilization of coconut shells and rice husks. Leveraging the potential of these natural resources can improve public access to clean and safe drinking water, thereby safeguarding public health. Based on this rationale, this study aims to examine the effectiveness of coconut shells and rice husks in improving the quality of dug well water in the riverbank areas of Cimahi City.

Materials and Methods

This study utilizes a Pretest-Posttest with Control Group design. A total of 27 samples of dug well water from the riverbank areas of Cimahi City were collected. Based on two treatment groups and one control group, each group consisted of nine samples. The first treatment involved the use of coconut shells, while the second treatment utilized rice husks, each applied to 10 liters of dug well water over a 24-hour period. The experiment was conducted in three replicates. For each treatment and control group, parameters including TDS, DO, Turbidity, TSS, pH, Fe, and Mn were measured both before and after the water treatment process. These measurements were conducted at the Regional Environmental Laboratory of Cimahi City.

Turbidity was measured using a turbidimeter, with the procedure referencing SNI 06-6989.25-2005. TSS are defined as particles larger than 2 microns present in water, with a maximum quality standard of 50 mg/L. According to the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, the quality standard for TDS in water is less than 300 mg/L. Furthermore, Government Regulation of the Republic of Indonesia Number 82 of 2001 stipulates that the minimum DO level for sanitation water is 4 mg/L. pH levels were examined using a pH meter and litmus paper, following the SNI 06-6989.11-2004 standard. Fe analysis was performed using a UV-Vis Spectrophotometer (2008), cuvettes, Erlenmeyer flasks, graduated cylinders, dropping pipettes, and a stopwatch, with the procedure referencing

SNI 6989.4:2009. Similarly, Mn was analyzed using cuvettes and a UV-Vis Spectrophotometer, in accordance with SNI 6989.5:2009.

The preparation of activated coconut shell charcoal involved cleaning the shells, followed by carbonization into charcoal, drying, and grinding into a fine powder. Rice husk charcoal was prepared by washing, sun-drying, and burning the husks. For the filtration process, 10 liters of dug well water samples were poured into separate containers. The filtration layers were constructed by placing coconut shell charcoal powder and rice husk ash at the bottom of the vessel, followed by a layer of sand, and finally a layer of gravel. Each layer maintained a thickness of approximately 5 cm. The well water was poured slowly onto the filter bed, allowing it to percolate through the gravel, sand, and charcoal layers, where impurities and pollutants were adsorbed. The purified water was then collected at the bottom of the container. This experiment was conducted in three replicates, followed by data collection. Data analysis to evaluate the effects of coconut shells and rice husks on TDS, DO, Turbidity, TSS, pH, Fe, and Mn levels was performed using a dependent t-test. Additionally, an ANOVA test was conducted to determine the differences in these parameters between the treatment groups and the control group.

Results and Discussion

The results of the study showed that the initial Turbidity of the dug well water was 54.3 NTU. The most significant reduction occurred after filtration using coconut shell charcoal, dropping to 0.8 NTU. The initial TDS level was 243 mg/L, with the greatest decrease observed in the coconut shell charcoal group, reaching 230 mg/L. For TSS, the initial concentration was 62.9 mg/L; however, the combined use of coconut shell charcoal and rice husk charcoal resulted in the most substantial reduction to 1.7 mg/L.

Regarding chemical parameters, the initial Fe concentration was 0.03 mg/L, which decreased to 0.02 mg/L after coconut shell charcoal filtration. The initial Mn level was 0.2 mg/L; notably, after treatment in the control group (using only gravel and sponge) as well as the coconut shell and rice husk charcoal groups, the level dropped to 0.03 mg/L. The pH of the well water was initially 6.6 S.U., with the highest increase observed after coconut shell charcoal filtration, reaching 7.08 S.U. Similarly, the DO level increased from an initial 6.04 mg/L to a peak of 7.4 mg/L following coconut shell charcoal treatment. These results are summarized in Table 1

Table 1. Assessment of Water Quality in Dug Well

Parameter	Baseline		Control Group		Coconut Shell		Rice Husk	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Turbidity	54.3	0.1	10.8	0.13	0.8	0.05	1.4	0.07
TDS	243	2.6	237	2.3	230	3.6	235	3.5
TSS	62.9	0.06	9	2.3	1.7	0.1	1.7	0.17
Fe	0.03	0.01	0.03	0.01	0.02	0.01	0.03	0.001
Mn	0.2	0.06	0.03	0.008	0.03	0.006	0.03	0.007
pH	6.6	0.02	6.8	0.03	7.08	0.02	6.9	0.005
DO	6.04	0.03	6.04	0.03	7.4	0.03	7.1	0.03

*SD = Standard Deviation

The results indicated that turbidity, TDS, TSS, and Mn levels in dug well water significantly decreased following filtration using all treatment media: the control group (gravel and sponge), coconut shell charcoal, and rice husk charcoal ($p < 0.05$). Conversely, Fe concentrations remained unchanged in the control group and showed no significant reduction in either the coconut shell or rice husk charcoal groups ($p > 0.05$). Regarding acidity, a significant increase in pH was observed across all filtration groups ($p < 0.05$). Furthermore, while DO levels did not improve significantly in the control group ($p > 0.05$), significant increases were recorded in both the coconut shell and rice husk charcoal treatments ($p < 0.05$). These findings are summarized in Table 2.

Table 2. Comparison of Dug Well Water Quality Before and After Intervention

Parameter	Control Group		Coconut Shell		Rice Husk	
	Difference	p	Difference	p	Difference	p
Turbidity	43.5	0.001	53.5	0.001	52.9	0.001
TDS	13	0.01	8	0.001	6	0.001
TSS	53.9	0.01	61.2	0.001	61.2	0.001
Fe	0	0.996	0.005	0.202	0.001	0.801
Mn	0.2	0.01	0.2	0.001	0.2	0.001
pH	0.1	0.01	0.5	0.001	0.3	0.001
DO	0.001	0.943	1.4	0.001	1.09	0.001

*SD = Standard Deviation

Statistical analysis revealed significant differences in turbidity, pH, and DO levels among all treatment groups, specifically between the control (gravel and sponge) and coconut shell charcoal, between the control and rice husk charcoal, and between the two types of charcoal ($p < 0.05$). For TDS and TSS, significant differences were observed when comparing the control group to both the coconut shell and rice husk charcoal treatments ($p < 0.05$).

Conversely, there were no significant differences in Fe and Mn concentrations across all three groups control, coconut shell charcoal, and rice husk charcoal ($p > 0.05$). These findings are summarized in Table 3.

Table 3. Comparison of Dug Well Water Quality Parameters Across Groups Post-Intervention

Parameter	Sample Group	mean	p	Inter-group Comparison	p
Turbidity	CG	10.8	0.001	CG - CS	0.001
	CS	0.8		CG - RH	0.001
	RH	1.4		CS – RH	0.001
TDS	CG	237	0.002	CG - CS	0.001
	CS	230		CG - RH	0.171
	RH	235		CS – RH	0.009
TSS	CG	9	0.001	CG – CS	0.001
	CS	1.7		CG - RH	0.001
	RH	1.7		CS – RH	1.000
Fe	CG	0.03	0.472	CG - CS	0.755
	CS	0.02		CG - RH	1.000
	RH	0.03		CS – RH	1.000
Mn	CG	0.03	0.944	CG - CS	1.000
	CS	0.03		CG - RH	1.000
	RH	0.03		CS – RH	1.000
pH	CG	6.8	0.001	CG - CS	0.001
	CS	7		CG - RH	0.001
	SP	6.9		CS – RH	0.001
DO	CG	7.1	0.001	CG – CS	0.001
	CS	7.4		CG - RH	0.001
	RH	6		CS - RH	0.001

*CG= Control Group, CS= Coconut Shell, RH= Rice Husk

Turbidity

Turbidity is a measure of water clarity and serves as a critical parameter in water treatment; potable water must comply with established standards, typically measured in Nephelometric Turbidity Units (NTU) (Nasier & Abdulrazzaq, 2022). Turbidity is a crucial physical standard as it directly affects the aesthetic quality of drinking water. It is caused by the presence of organic and inorganic materials, such as silt and substances derived from wastewater discharge. Furthermore, elevated turbidity levels are often associated with wastewater contamination (Al-Ramahi et al., 2023). The analysis revealed that turbidity levels exceeded the maximum permissible limits. These findings indicate that the studied dug well water is contaminated with organic and inorganic matter, including silt and substances originating from wastewater discharge.

The turbidity values observed in this study indicate that the dug well water is non-potable. During rainfall, surface runoff transports suspended sediments from the surrounding land into the wells. Turbidity refers to the reduction in water clarity caused by the presence of suspended and colloidal particles, including silt, organic and inorganic matter, and aquatic microorganisms. The relationship between suspended solids and turbidity is direct; an increase in TSS concentration leads to higher turbidity values (Adjovu et al., 2023). Increased levels of dissolved solids do not consistently result in higher turbidity; for instance, seawater typically contains high dissolved solid concentrations yet exhibits low turbidity. In this study, turbidity remained high at the sampling points, particularly in residents' wells. This condition is attributed to the proximity of the wells to the river, which introduces materials that remain in suspension and fail to settle.

TDS

TDS represents the concentration of dissolved substances in water that requires rigorous monitoring. Excessive TDS levels that deviate from established standards render water unsuitable for domestic use. For hygiene and sanitation purposes, the average TDS value must remain below 300 mg/L. TDS encompasses dissolved matter (diameter < 10^{-6} mm) and colloidal particles (diameter 10^{-6} mm to 10^{-3} mm), including chemical compounds and other substances that can pass through a 0.45 μm filter membrane (Stephen et al., 2023). TDS of the dug well water was recorded at 243 mg/L. A significant reduction in TDS levels was observed following a filtration process utilizing a combination of gravel, sponges, coconut shell biochar, and rice husk biochar. Elevated TDS concentrations in the raw water source are attributed to mineral weathering, soil runoff, and the infiltration of domestic wastewater.

High TDS levels can contaminate water bodies and pose significant risks to human health. According to the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023, the maximum permissible TDS level for sanitary purposes is < 300 mg/L. Statistical analysis revealed a significant difference in TDS reduction when comparing filtration using only gravel and sponges against filtration integrated with coconut shell biochar, as well as against rice husk biochar. Conversely, no significant difference was observed between the performance of coconut shell and rice husk biochar. Water quality testing in South Cimahi indicates that the dug wells are moderately contaminated by both natural processes and anthropogenic activities. The TDS levels near the maximum threshold are likely influenced by industrial activities in the vicinity of the sampling sites.

TSS

TSS levels in the dug well water remain elevated. Statistical analysis demonstrates a significant difference in TSS reduction between filtration using only gravel and sponges compared to filtration using coconut shell biochar, as well as compared to rice husk biochar. However, no significant difference was observed between the performance of coconut shell and rice husk biochar. The results indicate that activated carbon (biochar) is more effective in reducing TSS concentrations. According to Government Regulation (PP) No. 82 of 2001, the permissible TSS standard for potable water is 50 mg/L. High TSS levels in well water pose health risks, including gastrointestinal disorders and skin irritation, as these solids often serve as carriers for bacterial and pathogenic contamination (Verma et al., 2025). High TSS concentrations result in increased turbidity, compromising the water's aesthetic quality, taste, and odor. A reduction in TSS was observed following filtration using coconut shell biochar, rice husk biochar, and gravel media. In this system, gravel serves as a pre-filter to trap coarse impurities and create interstitial spaces that facilitate downward water flow. Furthermore, activated carbon (biochar) exhibits selective adsorption properties, enabling it to sequester specific gases and chemical compounds. It functions by effectively removing odors, discoloration, and residual chlorine, thereby enhancing water clarity and providing a neutral, fresh taste (Wawrzyniak et al., 2023).

Fe

The analysis of Fe concentrations in the dug well water revealed that levels remain within the permissible limits for clean water quality standards. Filtration using only gravel and sponges resulted in stagnant Fe levels. However, a reduction in Fe concentration was observed following filtration with coconut shell biochar, whereas rice husk biochar showed no significant impact on Fe removal. Maintaining Fe levels within regulatory standards is critical, as excessive iron intake is associated with adverse health effects, including gastrointestinal disorders, skin irritations (such as acne), and potential long-term damage to the pancreas, heart, and kidneys. The effectiveness of coconut shell biochar in reducing Fe is attributed to a combination of mechanical filtration and adsorption mechanisms. When processed into activated carbon, coconut shell biochar develops an extensive microporous structure that effectively sequesters iron ions from the aqueous solution (Jasna et al., 2021).

Coconut shell biochar functions as an effective adsorbent, a material whose surface possesses the capability to attract and bind other substances. The extensive internal porosity of the biochar provides a high specific surface area, which is essential for the adsorption process. As water percolates through the filter media, dissolved iron ions adhere to and are adsorbed onto the biochar surface. In addition to chemical adsorption, a physical filtration mechanism occurs where oxidized iron particles, such as rust, are mechanically trapped within the biochar layers. Furthermore, the chemical activation of rice husk biochar using Sodium Chloride (NaCl) can enhance its efficacy in reducing iron concentrations by increasing its active surface sites (Alam et al., 2020). The activation process aims to expand the pore surface area and enhance the adsorption capacity of the biochar. In this filtration system, rice husk biochar is utilized as a core functional layer. As the well water permeates through the filter media containing the rice husk biochar, the effluent exhibits a significantly reduced concentration of iron Fe due to the increased availability of active binding sites.

Mn

The concentration of Mn in the dug well water was found to exceed the quality standard of 0.1 mg/L. However, a significant reduction was observed following filtration using a combination of gravel, sponges, coconut shell biochar, and rice husk biochar. Manganese is a silver-gray, highly reactive metal that readily interacts with ions in both water and air (Riad, 2025). Excessive Mn levels in well water contribute to central nervous system disorders, such as tremors and memory impairment, as well as aesthetic issues including unpleasant taste, odor, and brownish staining on laundry. While Mn is essential in trace amounts for metabolism and neurological function, concentrations exceeding the World Health Organization (WHO) threshold of 0.1 mg/L for drinking water pose serious health risks. The reduction of Mn levels in this study is primarily attributed to the adsorption process facilitated by the coconut shell biochar(Ni`mah et al., 2022). The pore structure of coconut shell biochar, particularly when processed into activated carbon, exhibits a high affinity for attracting and binding metallic ions, such as manganese, from the permeating water. This mechanism effectively reduces the concentrations of Mn and Fe in dug well water, thereby significantly enhancing the overall water quality.

pH

The pH levels of the dug well water were found to be within the established quality standards. However, a statistically significant increase in pH was observed across all filtration groups, with significant differences recorded between the control (gravel and sponges), coconut shell biochar, and rice husk biochar treatments. The safe pH range for potable water is established between 6.5 and 8.5 S.U. Extremes in pH, whether highly acidic or highly alkaline, often indicate the presence of contaminants and pose health risks. Acidic water (low pH) can lead to the erosion of tooth enamel and gastrointestinal disturbances, while highly alkaline water (high pH) can adversely affect taste and result in mineral scaling on household equipment (Inchingolo et al., 2023). Coconut shell biochar elevates the pH of well water by acting as an adsorbent that effectively removes acid-inducing substances. Once activated, the biochar possesses an exceptionally high specific surface area and a sophisticated pore network capable of sequestering various impurities, including acidic ions that contribute to low pH levels. This adsorption process neutralizes the water, shifting its chemical profile toward a more balanced, alkaline state.

Rice husk biochar increases the pH of well water due to its inherent alkaline properties, derived from the residual ash produced during the carbonization process. This alkalinity effectively neutralizes water that tends to be acidic, thereby elevating the overall pH level. Rice husk naturally contains essential mineral elements, such as potassium (K), calcium (Ca), and magnesium (Mg), which contribute to its acid-neutralizing capacity (Polytechnic et al., 2024). Upon immersion in water, the alkaline compounds within the rice husk biochar are gradually released into the aqueous solution. These alkaline constituents react with hydrogen ions (H^+) the primary drivers of acidity thereby neutralizing the water and elevating its pH level. Furthermore, rice husk biochar possesses a microporous structure capable of adsorbing other acid-inducing substances; however, the predominant mechanism for pH elevation remains the leaching of its inherent mineral content.

DO

The DO levels in the dug well water were found to comply with regulatory standards. Statistical analysis revealed significant differences in DO concentrations across all treatment groups, with distinct variations observed between the control (gravel and sponges), coconut shell biochar, and rice husk biochar. Notably, coconut shell biochar, when processed into activated carbon, contributes to an indirect increase in DO levels. This enhancement is primarily achieved through the efficient removal of organic pollutants and other oxygen-demanding substances, thereby reducing the Biochemical Oxygen Demand (BOD) and allowing the dissolved oxygen to remain at optimal concentrations (Po et al., 2023). The primary mechanism for stabilizing DO levels involves the adsorption of oxygen-consuming substances within the water. Activated carbon, characterized by its extensive surface area and microscopic pores, is highly efficient in the adsorption of dissolved organic compounds, such as humic and fulvic acids. These organic compounds serve as a primary substrate for microbial growth. When microorganisms metabolize these substances, they consume dissolved oxygen through aerobic respiration, leading to a depletion of DO levels. By effectively sequestering these organic loads, activated carbon limits microbial activity, thereby preventing oxygen depletion and maintaining stable DO concentrations in the filtered water (Salisu et al., 2023).

Rice husk biochar enhances DO levels by clarifying the water and eliminating oxygen-consuming contaminants. The filtration process improves water quality, allowing oxygen to dissolve more effectively and remain stable. When activated, rice husk biochar develops an extensive network of microscopic pores that function as an adsorbent to trap organic matter, chemicals, and heavy metals. By sequestering these organic pollutants, the biochar significantly reduces the available substrate for aerobic bacteria. Under normal contaminated conditions, these bacteria consume substantial amounts of dissolved oxygen to decompose organic matter. Consequently, the reduction in microbial activity prevents the depletion of oxygen, leading to an increase in DO concentrations. Furthermore, activated biochar is effective in removing odorous compounds such as hydrogen sulfide (H_2S), which typically serves as an indicator of organic pollution in groundwater (Nuraiti & Izhar, 2022).

Conclusion

The filtration process, utilizing a combination of gravel, sponges, coconut shell biochar, and rice husk biochar, resulted in a significant reduction in Turbidity, TDS, TSS, and Manganese (Mn) levels. In contrast, Iron (Fe) concentrations remained unchanged following filtration with gravel and sponges alone, and no significant decrease was observed after the addition of either biochar type. Regarding the chemical and gaseous profiles, a significant increase in pH was recorded across all treatment groups. While DO levels did not show a significant improvement with gravel and sponge filtration alone, a significant increase was achieved when the system integrated coconut shell or rice husk biochar. Comparative analysis revealed that Turbidity, pH, and DO showed significant differences when comparing the control (gravel/sponges) to both biochar treatments, as well as between the two types of biochar themselves. For TDS and TSS, significant differences were found between the control and each biochar treatment. However, no significant inter-group differences were observed for Fe and Mn concentrations among the various filtration media.

Statistical comparisons revealed that Turbidity, pH, and DO levels exhibited significant differences across all pair-wise comparisons: between the control (gravel/sponges) and coconut shell biochar, between the control and rice husk biochar, and notably, between the coconut shell and rice husk biochar treatments themselves. For TDS and TSS, significant differences were observed when comparing the control group to either coconut shell or rice husk biochar. However, no significant differences were found between the two types of biochar for these parameters. Furthermore, Fe and Mn concentrations showed no significant inter-group differences, indicating that the reduction or stability of these metallic ions was consistent across the control and both biochar-integrated filtration systems.

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