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Examining the Levels of Various Physicochemical Parameters in Polluted Water Environment Treated with Bio-adsorbents

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ABSTRACT

This research investigated the efficacy of bio-adsorbents in treating contaminated water environments by examining the concentration of various physicochemical parameters. Specifically, different sizes of palm fruit fibers were studied to determine their effectiveness in water treatment. The study monitored changes in Total Petroleum Hydrocarbon (TPH) concentration and other physicochemical properties of contaminants before and after treatment with each fiber sample. The experiment demonstrated a reduction in TPH concentration as contaminated water passed through each sample container, influenced by temperature variations. Morphological analysis of the palm fruit fibers (both room-dried and sun-dried) revealed varying concentrations of elements crucial for bio-adsorption. Sun-dried fibers exhibited higher levels of calcium (Ca), oxygen (O2), carbon (C), and sulfur (S), whereas room-dried fibers showed elevated concentrations of magnesium (Mg), silicon (Si), iron (Fe), potassium (K), and sodium (Na). These findings underscored the temperature-dependent effectiveness of bio-adsorbents in treating contaminants, thereby mitigating the presence of toxic substances in polluted water environments. The study contributes to understanding how operational temperatures affect the rate of contaminant removal, crucial for optimizing bio-adsorbent performance in water treatment applications.

Keywords: physicochemical, remediation, cleanup, environmental, soil

1. INTRODUCTION

The ecosystem in regions like the Niger Delta, heavily affected by crude oil exploration activities, faces significant challenges due to continual discharge of effluents and spills, particularly in waterlogged areas. Efforts to mitigate these environmental impacts have increasingly relied on bioremediation techniques, where temperature plays a crucial role [1]. Temperature variations influence the effectiveness of adsorbents and microbial activities within treatment units or columns, with different organisms thriving optimally within specific temperature ranges: mesophilic (< 20 to < 45°C), thermophilic (< 20 to < 75°C), and super thermophilic (< 20 to < 105°C) [2].

Industrially active areas, such as those involved in crude oil processing, significantly contribute to water pollution and contamination, necessitating effective cleanup strategies. Early research in the 1980s highlighted microorganisms' ability to accumulate metallic elements through active metabolic processes. Subsequent toxicological studies focused on the impacts of metal accumulation on microbial metabolism and its repercussions on the food chain [3-5]. However, recent investigations have shown that even inactive or dead microbial biomass can passively bind metal ions through various physicochemical mechanisms, sparking renewed interest in biosorption research.

Biosorption, a natural physicochemical process, involves the passive concentration and binding of contaminants onto the cellular structures of certain biomasses [6-7]. This process depends not only on biomass type and composition but also on external physicochemical factors and solution chemistry. Mechanisms underlying biosorption include ion exchange, complexation, coordination, adsorption, electrostatic interaction, chelation, and micropredation [8-10].

In practical terms, biosorption distinguishes from bioaccumulation, where living microorganisms actively accumulate contaminants, by employing dead biomass to passively bind pollutants [11]. This distinction underscores the diverse applications and mechanisms inherent in biosorption processes, crucial for developing effective strategies to mitigate water contamination in polluted environments.

2. METHODOLOGY

2.1. Sample collection

Freshwater samples were gathered from the Orashi region of Nigeria and subsequently transported to a laboratory at Rivers State University in Port Harcourt. Crude oil was sourced from a local oil company based in Port Harcourt, Rivers State, Nigeria, specifically for use in the experiment. Additionally, palm fruit fiber was collected from a farm in Ahoada, Rivers State, Nigeria..

2.2. Sample Preparation

The freshwater samples were distributed among three separate containers and subsequently contaminated with crude oil obtained from an oil company based in Port Harcourt, Rivers State, Nigeria.

The palm fruit fiber was divided into two groups: one was subjected to drying at room temperature, while the other was left outdoors to dry naturally in the sun. Following this, the dried palm fruit fiber was crushed into various particle sizes.

All samples were prepared to fit appropriately within the specimen chamber and securely mounted on a specimen holder known as a specimen stub. Several models of scanning electron microscopes (SEM) are capable of examining any part of a 6-inch (15 cm) semiconductor wafer, with some models capable of tilting an object of that size up to 45 degrees.

2.3. Microbial Isolation and Identification

The microorganisms found in both the crude oil and water samples were isolated, identified, and enumerated using a medium suitable for aerobic heterotrophic bacteria, specifically selected for isolating non-fastidious bacteria.

2.4. Model Development

$$\begin{Bmatrix} Rate\ of\ inflow \\ of\ subs.into \\ the\ reactor \end{Bmatrix} - \begin{Bmatrix} Rate\ of\ outflow \\ of\ subs.out\ of \\ the\ reactor \end{Bmatrix} \pm \begin{Bmatrix} Rate\ of\ gen.or \\ cons.within \\ the\ reactor \end{Bmatrix} = \begin{Bmatrix} Rate\ of\ accum. \\ within\ reactor \end{Bmatrix} \quad (1)$$

The equation can be further express as:

$$v\frac{dS}{dt} = \frac{dS_i}{dt} - \frac{dS_0}{dt} \pm \frac{dS}{dt} \quad (2)$$

But $\frac{dS_i}{dt}$ *and* $\frac{dS_0}{dt}$ could be expressed in terms of flow rate

$$\frac{dS_i}{dt} = kapS_i \quad (3)$$

$$\frac{dS_0}{dt} = kapS_0 \quad (4)$$

$$\frac{dS}{dt} = \text{h}\frac{dS}{dt} \quad (5)$$

Where:

k = mass transfer co-efficient

a = effective interface area per unit

h = height of the packed bed

p = pressure

Upon substituting the equations (3),(4) and (5) into equation (2), we have

$$v\frac{dS}{dt} = kapS_i - kapS_0 \pm \text{h}\frac{dS}{dt} \quad (6)$$

At steady conditions

$$v\frac{dS}{dt} = 0 \quad (7)$$

$$kapS_i - kapS_0 = -\text{h}\frac{dS}{dt} \quad (8)$$

Dividing through equation (8) by h, we have

$$\frac{dS}{dt} = \frac{kapS_i}{\text{h}} - \frac{kapS_0}{\text{h}} \quad (9)$$

$$\frac{dS}{dt} = --\frac{kap}{\text{h}}[S_i - S_0] \quad (10)$$

Where: $S_i - S_0$ is the change in concentration of the TPH.

$$S_i - S_0 = \Delta S \quad (11)$$

$$\frac{dS}{dt} = --\frac{kap}{\text{h}}\Delta S \quad (12)$$

Recalling Monod's equation

$$\mu = \frac{\mu_{max}+S}{K_m+[S]} \qquad (13)$$

Expressing equation (13) in terms of adsorption/biodegradation

$$\gamma = --\frac{kap}{h}\Delta S \qquad (14)$$

Likewise equation (12) can be link to Michael's Menten equation

$$v = \frac{V_{max.}\cdot S}{K_s+[S]} \qquad (15)$$

This implies that

$$\gamma = v = \mu \qquad (16)$$

$$\frac{V_{max.}\cdot S}{K_s+[S]} = -\frac{kap}{h}\Delta S \qquad (17)$$

$$\frac{V_{max}Sh}{kpa(k_s+[S])} = -\Delta S \qquad (18)$$

$$\frac{V_{max}Sh}{kpa(k_s+[S])} = S_0 - S_i \qquad (19)$$

$$v = \frac{dS}{dt} \qquad (20)$$

Where dS = $S_0 - S_i$ (21)

$$\int_{S_0}^{S_i} dS = v\int_0^t dt \qquad (22)$$

$$S_i - S_0 = vt \qquad (23)$$

$$\frac{V_{max}Sh}{kpa(k_s+[S])} = -vt \qquad (24)$$

$$V_{max}Sh = -vt(kpa(k_s+[S])) \qquad (25)$$

$$V_{max}Sh = -vtkpak_s - vtkpa[S] \qquad (26)$$

$$V_{max}Sh + vtkpa[S] = -vtkpak_s \qquad (27)$$

$$s(v_{max}h + vtkap) = -vtkpak_s \qquad (28)$$

$$s = \frac{-vtkpa\,k_s}{(v_{max}h+vtkap)} \qquad (29)$$

$$\frac{1}{s} = -\frac{(v_{max}h+vtkap)}{vtkpa\,k_s} \qquad (30)$$

$$\frac{1}{s} = -\frac{v_{max}h}{vtkpa\,k_s} - \frac{1}{k_s} \qquad (31)$$

3. RESULTS AND DISCUSSION

This section presents graphical figures and discusses the results obtained from comparing various physicochemical parameters treated with bio-adsorbents in a polluted water environment.

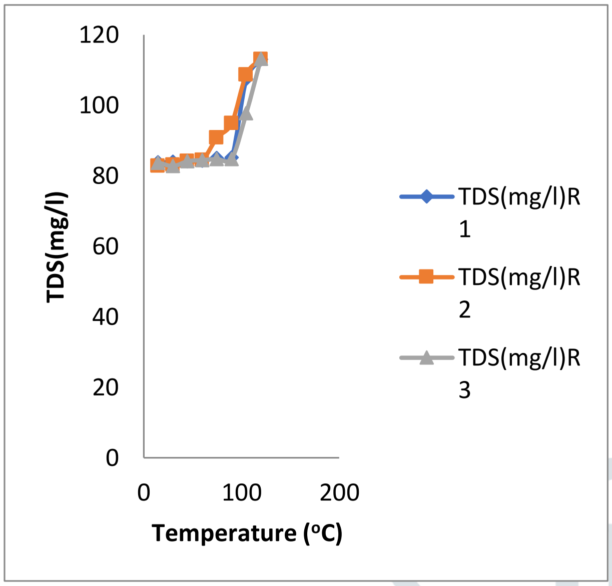


Figure 1: The relationship between Total Dissolved Solid (TDS) concentration and temperature effects on different water samples labeled R1 – R3 treated with sun-dried palm fruit fiber adsorbent.

The plot in Figure 1 shows decrease in total dissolved solid (TDS) concentration with increase in temperature. The increase in temperature influenced the gradation of contact and adsorption in the order of TDS1 > TDS2 > TDS3. The changes in TDS can be due to the changes in temperature as seen in Figure 1.

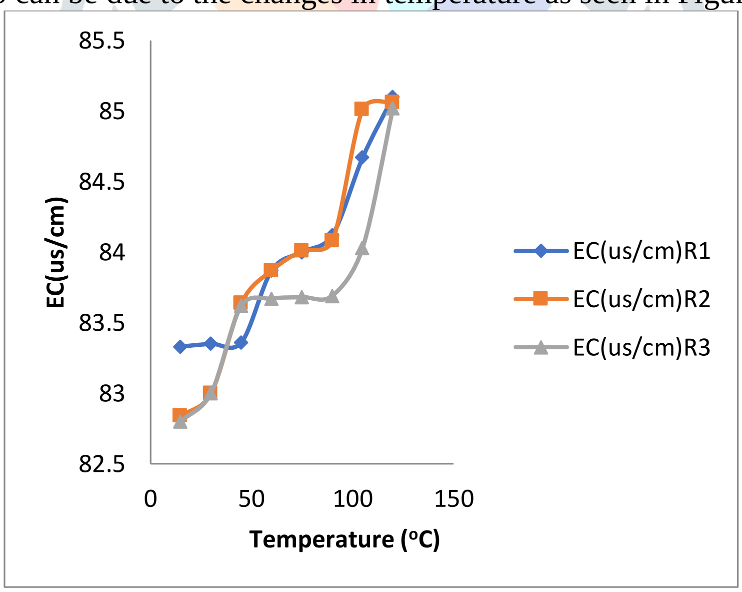


Figure 2: The variation in Electrical Conductivity (EC) concentration with respect to temperature effects on different water samples labeled R1 – R3 treated with sun-dried palm fruit fiber adsorbent.

Figure 1 illustrates the increase in electrical conductivity concentration with respect to temperature across the various samples studied. Notably, intercepts in EC concentration were observed at temperatures of 35°C, 55°C, and 12°C.

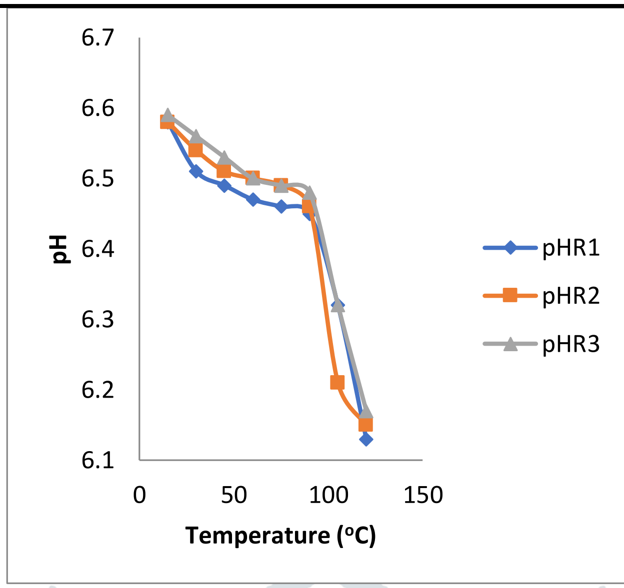


Figure 3: The variation in pH concentration with respect to temperature for different water samples labeled R1 – R3 treated with sun-dried palm fruit fiber adsorbent.

The figure illustrates a decrease in pH values, indicating changes in acidity levels. Sample 3 exhibited superior performance compared to samples 1 and 2. These results underscore the bioadsorbent's capability to facilitate the restoration of contaminated water integrity.

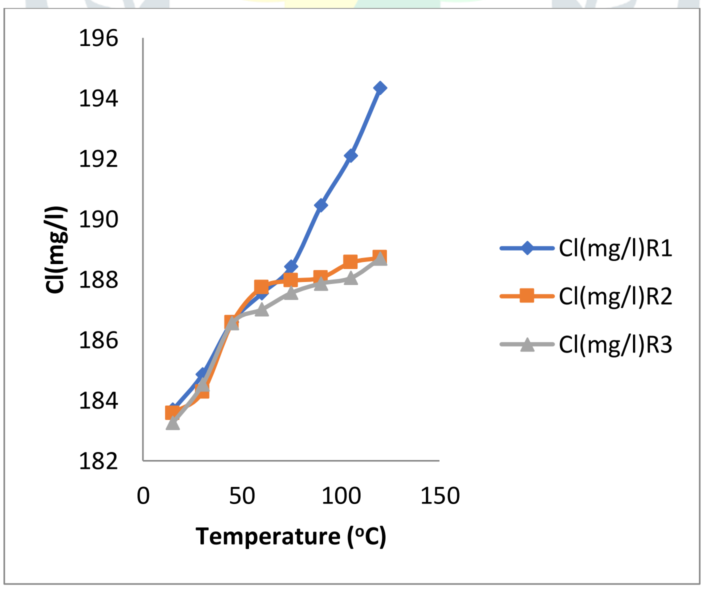
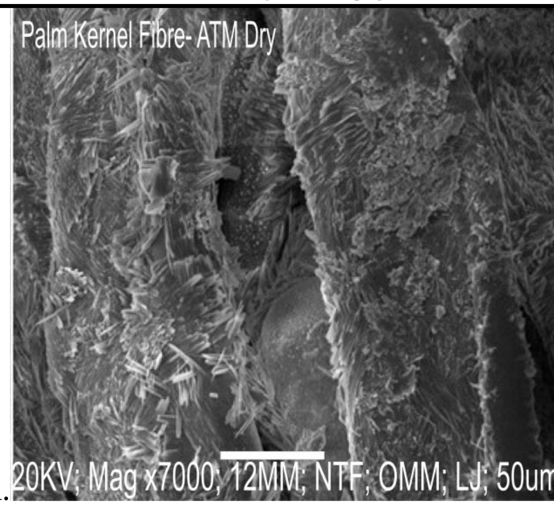


Figure 4: The relationship between Chloride (Cl) concentration and temperature effects on various water samples labeled R1 – R3 treated with sun-dried palm fruit fiber adsorbent.

The study revealed that all samples exhibited similar behavior. An increase in chloride (Cl) concentration was observed with rising temperature, and this trend was consistent across all samples investigated. Additionally,



there were instances where intercepts occurred along this trend.

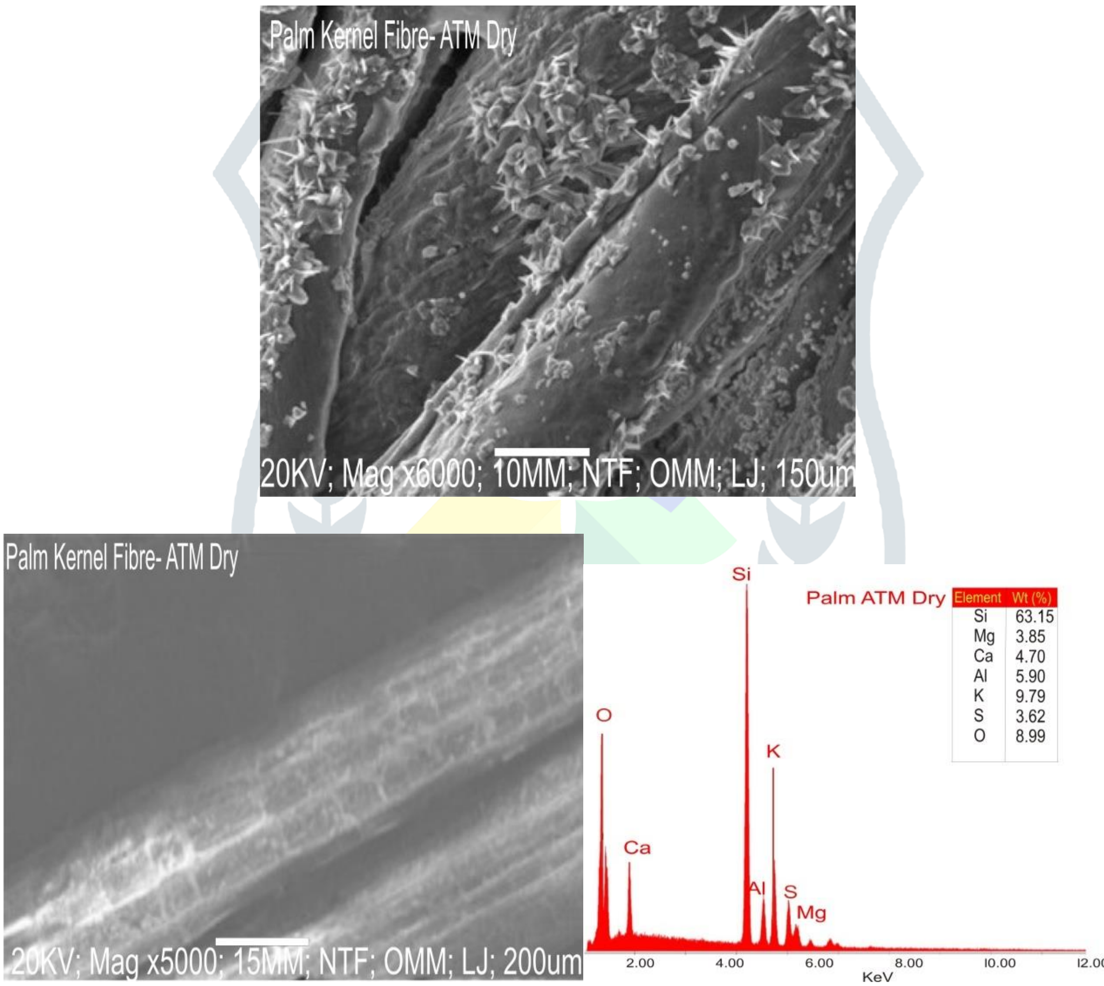


Figure 5: Description of Palm Fruit Fiber Morphology after Sun Drying and Elemental Composition

A morphological analysis was carried out for the experimented palm fruit fibre of different particle sizes subjected into Sun Dry as shown in Figure 5. The elements identified are Silicon (Si) of 63.15 wt(%), magnesium (mg) of 3.85 wt(%) calcium (Ca) of 4.70 wt(%), Aluminium (Al) of 5.90 wt(%), Potassium (K) of 9.79 wt(%), Surphur (S) of 3.26 wt(%) and oxygen (O) of 8.99 wt(%) for Palm Karnel fibre of sun dry

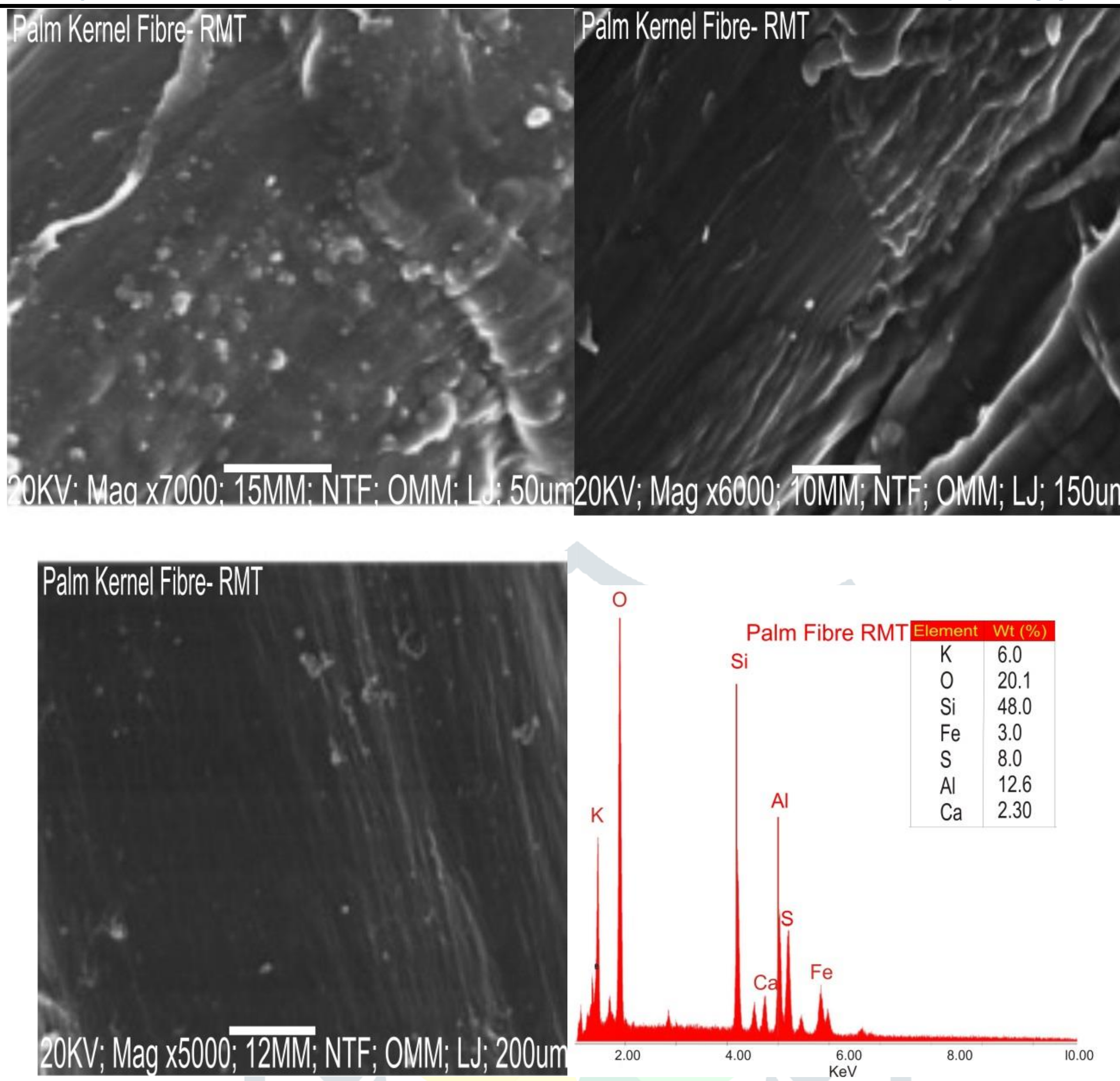


Figure 6: Description of Palm Fruit Fiber Morphology after Room Drying and Elemental Composition

A morphological analysis was conducted on the experimental palm fruit fiber of various particle sizes subjected to room drying, as illustrated in Figure 6. The elements identified for room-dried fibers are as follows: K = 6.0 wt%, O = 20.1 wt%, Si = 48.0 wt%, Fe = 3.0 wt%, S = 8.0 wt%, Al = 12.6 wt%, and Ca = 2.30 wt%.

4. CONCLUSION

The application of bioadsorbents in packed bed units connected in series effectively treated contaminated water, resulting in notable changes in TDS, temperature, pH, chloride, and sulfate concentrations. Each bioadsorbent demonstrated significant effectiveness in reducing these parameters to levels within the acceptable limits set by the WHO. Temperature emerged as a critical factor influencing the variation in these physicochemical properties throughout the treatment process. These findings underscore the potential of bioadsorption technology in mitigating water pollution and highlight the importance of temperature control in optimizing treatment outcomes.

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