

Review on Removal of Saline Water Na⁺ Ion Using Banana Stem Extract and Other Agricultural Adsorbents

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Abstract—Increasing salinity in water resources has become a major environmental and public health challenge worldwide. The presence of high concentrations of sodium ions (Na⁺) in saline water affects drinking water quality, soil fertility, and agricultural productivity. Conventional desalination technologies such as membrane filtration and thermal distillation are effective but require high energy consumption and operational costs. Recently, agricultural waste-based adsorbents have gained significant attention as sustainable and low-cost alternatives for ion removal from saline water. Among these materials, banana stem extract and banana pseudo-stem derived adsorbents have shown promising adsorption potential due to their high cellulose content and abundant functional groups capable of binding ions. This review summarizes recent studies on the use of banana stem extract and other agricultural adsorbents such as rice husk, coconut shell, sugarcane bagasse, and orange peel for sodium ion removal. The adsorption mechanisms, influencing parameters, and adsorption models are discussed. The review highlights the potential of agricultural waste materials as environmentally friendly adsorbents for sustainable desalination and saline water treatment.

Index Terms—Saline water treatment, sodium ion removal, banana stem extract, agricultural waste adsorbents, adsorption, desalination.

I. INTRODUCTION

Salinity in water bodies has become an increasing environmental concern due to industrial discharge, seawater intrusion, irrigation return flows, and climate change [1]. Elevated concentrations of sodium ions (Na⁺) in water cause serious environmental and health problems, including soil salinization, reduced agricultural productivity, and deterioration of drinking water quality [2]. Traditional desalination techniques

such as Reverse Osmosis, thermal distillation, and electrodialysis are widely used to remove salts from seawater and brackish water [3]. However, these technologies require high energy input, sophisticated infrastructure, and high operational costs.

In recent years, adsorption has emerged as an effective and economical method for removing dissolved ions from water. Adsorption processes utilize solid materials known as adsorbents that can bind dissolved ions onto their surface through physical or chemical interactions [4].

Agricultural waste materials such as banana stem, coconut shell, rice husk, and sugarcane bagasse are increasingly being investigated as low-cost adsorbents due to their availability, biodegradability, and high adsorption capacity [5].

II. BANANA STEM EXTRACT AS AN ADSORBENT FOR ION REMOVAL

Banana plants generate a large amount of biomass waste after fruit harvesting. The banana pseudo-stem is rich in cellulose, hemicellulose, and lignin, which contain functional groups such as hydroxyl (–OH), carboxyl (–COOH), and carbonyl groups capable of binding metal ions and salts.

Studies have demonstrated that banana stem derived materials can effectively remove various ions from water through adsorption mechanisms.

For example, banana pseudo-stem biosorbents have been successfully used to remove heavy metals such as copper ions from aqueous solutions, showing strong adsorption performance under optimized conditions of pH, adsorbent dosage, and contact time [6]. Similarly, banana stem adsorbents have also been used to remove chromium ions from contaminated water with removal efficiencies exceeding 80% under optimized

experimental conditions [7]. Activated carbon produced from banana stems has also demonstrated high adsorption capacity due to its large surface area and porous structure, making it suitable for water purification applications [8]. These studies indicate that banana stem biomass can be converted into efficient bio-adsorbents for removing ions from water.

III. MECHANISM OF SODIUM ION ADSORPTION

The adsorption of sodium ions (Na^+) onto banana stem-based adsorbents occurs through several physicochemical mechanisms that depend on the surface properties of the biomass material. One of the primary mechanisms is ion exchange, in which sodium ions present in saline water replace naturally occurring ions such as calcium, potassium, or hydrogen ions on the surface of the adsorbent. Another important mechanism is electrostatic interaction, where functional groups such as hydroxyl ($-\text{OH}$) and carboxyl ($-\text{COOH}$) present in the lignocellulosic structure of banana stem attract the positively charged sodium ions through electrostatic forces [9]. In addition, surface complexation plays a significant role, in which sodium ions form coordination complexes with functional groups located on the adsorbent surface, thereby enhancing the adsorption capacity. Furthermore, physical adsorption also contributes to sodium ion removal; the porous structure of banana stem biomass provides numerous micro- and mesopores that can trap sodium ions through weak intermolecular forces such as van der Waals interactions. These combined mechanisms enable banana stem-derived adsorbents to effectively remove sodium ions from saline water.

IV. OTHER AGRICULTURAL WASTE ADSORBENTS FOR Na^+ REMOVAL

Several agricultural waste materials have been widely investigated for the treatment of saline water due to their natural adsorption properties and environmental sustainability. Among these, rice husk is considered a promising adsorbent because it contains a high amount of silica and lignocellulosic components, which provide numerous active sites for the adsorption of dissolved ions [10]. Coconut shell is another important agricultural by-product that is commonly converted into activated carbon; the resulting material possesses

high porosity and a large surface area, making it highly effective for ion removal from aqueous solutions [11]. Similarly, sugarcane bagasse, a residue from the sugar industry, contains cellulose fibers and various functional groups such as hydroxyl and carboxyl groups that can bind dissolved ions through adsorption mechanisms. Orange peel has also attracted attention as a natural adsorbent because it contains pectin and carboxyl functional groups that enhance its ability to capture ions from water. Due to their low cost, easy availability, biodegradability, and high adsorption potential, these agricultural wastes are considered promising materials for sustainable saline water treatment and desalination processes, particularly in agricultural regions where such biomass resources are abundantly available.

V. FACTORS AFFECTING ADSORPTION OF SODIUM IONS

Several parameters significantly influence the efficiency of the adsorption process in removing ions from saline water. One of the most important factors is the pH of the solution, as it affects both the surface charge of the adsorbent and the ionization of functional groups present on the adsorbent surface, thereby influencing the interaction between the adsorbent and the ions in solution. Another important parameter is the adsorbent dosage; increasing the amount of adsorbent generally enhances the adsorption efficiency because a higher dosage provides more active sites available for ion binding. Contact time also plays a crucial role in the adsorption process, as adsorption typically increases with increasing time until equilibrium is reached between the ions in solution and those attached to the adsorbent surface. Additionally, temperature affects the adsorption process by influencing the kinetics of adsorption and the diffusion rate of ions toward the adsorbent surface. Therefore, optimizing these parameters is essential for achieving maximum adsorption efficiency in saline water treatment processes.

VI. ADSORPTION ISOTHERM MODELS

Langmuir Isotherm

The Langmuir model assumes monolayer adsorption onto homogeneous surfaces.

$$q_e = \frac{q_{max} K_L C_e}{1 + K_L C_e}$$

Freundlich Isotherm

The Freundlich model describes adsorption on heterogeneous surfaces.

$$q_e = K_F C_e^{1/n}$$

These models are commonly used to evaluate adsorption capacity and mechanism.

VII. ADVANTAGES OF AGRICULTURAL ADSORBENTS

Agricultural waste-based adsorbents offer several significant advantages for water treatment applications. One of the main benefits is their low cost and easy availability, as these materials are generated in large quantities as by-products of agricultural activities. In addition, they are environmentally friendly and help in the effective utilization of agricultural residues that might otherwise be discarded or burned. These materials are also biodegradable, which makes them safer for environmental applications compared to synthetic adsorbents. After undergoing physical or chemical activation, many agricultural wastes exhibit high adsorption capacity due to the development of porous structures and the presence of functional groups capable of binding dissolved ions. Furthermore, many of these adsorbents show potential for regeneration and reuse, allowing them to be used in multiple treatment cycles. Because of these advantages, agricultural waste-derived adsorbents are considered highly attractive and sustainable materials for modern water treatment and desalination technologies.

VIII. CHALLENGES AND FUTURE RESEARCH

Despite the promising potential of agricultural waste-based adsorbents for saline water treatment, several challenges still remain. One of the major limitations is that only a limited number of studies have specifically focused on the removal of sodium ions from saline water using these materials. In addition, most of the research has been conducted at the laboratory scale, highlighting the need for further investigations on large-scale and practical applications. Another important challenge is the effective regeneration and reuse of adsorbents after the adsorption process, which

is necessary to ensure economic feasibility and long-term sustainability. Furthermore, optimization of adsorption conditions such as pH, temperature, contact time, and adsorbent dosage is required to achieve maximum ion removal efficiency. Future research should therefore focus on improving the performance of agricultural adsorbents through chemical or thermal activation methods, which can enhance their surface area, porosity, and functional groups, thereby increasing their adsorption efficiency for desalination and saline water treatment applications.

IX. CONCLUSION

The removal of sodium ions (Na⁺) from saline water is an important step toward improving water quality and addressing the growing global demand for freshwater resources. Agricultural waste-based adsorbents have emerged as promising, sustainable, and low-cost materials for water treatment applications. Among these materials, banana stem extract and banana stem-derived adsorbents have shown considerable potential due to their high cellulose content and the presence of functional groups such as hydroxyl and carboxyl groups that facilitate ion adsorption. In addition to banana stem, other agricultural wastes such as rice husk, coconut shell, sugarcane bagasse, and orange peel have also demonstrated effective adsorption capabilities for removing dissolved ions from water. The adsorption process is influenced by several factors including pH, adsorbent dosage, contact time, and temperature, which must be optimized to achieve maximum removal efficiency. Although these materials provide significant advantages such as low cost, environmental friendliness, biodegradability, and potential for regeneration, further research is needed to enhance their performance and scalability. Future studies should focus on improving adsorption capacity through chemical or thermal activation, understanding adsorption mechanisms in greater detail, and developing large-scale applications for saline water treatment. Overall, agricultural waste-based adsorbents offer a promising and sustainable approach for desalination and water purification technologies.

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