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Biofilters of The Future: Studying The Sorption Properties of Persimmon Seeds For Water Purification

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Abstract: In the context of the growing need for environmentally friendly and effective methods of water purification, the attention of researchers is attracted by natural sorbents. In this paper, the sorption properties of persimmon (Diospyros kaki) seeds are investigated as a potential biosorbent for removing pollutants from aqueous solutions. Experiments were conducted to determine the adsorption efficiency of heavy metals (e.g. lead and copper) and organic substances (e.g. phenol). Adsorption parameters such as capacity, kinetics and isotherms were estimated. The results showed that crushed and activated persimmon seeds have high sorption capacity, especially in an acidic environment. Thus, persimmon seeds are a promising, cheap and environmentally friendly material for creating new generation biofilters.

Keywords: Biosorbent, Persimmon Seeds, Water Purification, Heavy Metals, Natural Filter, Adsorption, Ecology, Sustainable Technologies.

Introduction

Rational use and protection of water resources are the most important conditions for sustainable socio-economic development of the Republic of Uzbekistan. In the context of active population growth, industrialization and climate change, the problem of water pollution is becoming increasingly important. The issue of removing toxic pollutants, such as heavy metals and organic compounds, which pose a threat not only to the environment but also to human health, is especially acute (Abdurakhmanova, 2021).

The legislation of the Republic of Uzbekistan defines the legal and organizational framework in the field of water resources protection. Thus, in accordance with the Law of the Republic of Uzbekistan "On Water and Water Use" (No. 837-XII of July 23, 1993), the state undertakes to ensure the rational use, restoration and protection of waters, as well as the prevention and reduction of their pollution (Law of the Republic of Uzbekistan, 1993). Additionally, the Law "On Nature Protection" (No. 754-XII of December 9, 1992) emphasizes the need to introduce environmentally friendly technologies and improve the efficiency of natural resource use (Law of the Republic of Uzbekistan, 1992).

The regulatory framework in the field of drinking water quality is enshrined in Resolution No. 149 of the Cabinet of Ministers of the Republic of Uzbekistan dated June 4, 2009, which approved the Sanitary Rules and Norms for Drinking Water (SanPiN No. 0170-09). According to this document, maximum permissible concentrations (MPC) of pollutants

such as lead, cadmium, copper, phenol and other hazardous compounds are established, the excess of which can lead to serious diseases, including poisoning, kidney, liver and central nervous system dysfunction (Resolution of the Cabinet of Ministers of the Republic of Uzbekistan, 2009).

Taking into account the requirements of these regulatory documents, the development and implementation of new, effective and inexpensive methods of water purification based on the principles of environmental safety and sustainable development is of particular relevance. As part of the implementation of the Strategy for the Transition of the Republic of Uzbekistan to a "Green" Economy for 2019-2030, approved by the Decree of the President of the Republic of Uzbekistan No. PP-4477 dated October 4, 2019, the need to introduce innovative and low-waste technologies in water purification is emphasized (Resolution of the President of the Republic of Uzbekistan, 2019).

In this context, special attention is paid to the study of natural biosorbents - cheap and accessible materials of plant origin that can effectively remove a wide range of pollutants. One of the promising such materials is persimmon seeds (Diospyros kaki), which, due to their porous structure and rich content of lignin, cellulose and phenolic compounds, can act as an effective adsorbent (Akhmedov, 2020), (Abduraimov, 2021), (Makhmudov, 2021).

The aim of this work is a comprehensive study of the sorption properties of persimmon seeds for water purification from heavy metals and organic pollutants, taking into account the requirements of the current regulations of the Republic of Uzbekistan. It is assumed that the use of this type of biosorbent can become the basis for the creation of environmentally friendly and affordable new-generation biofilters applicable both in everyday life and in industry (Abduraimov, 2021).

Methodology

The methodology of this study involved a comprehensive experimental approach to evaluate the sorption properties of persimmon (*Diospyros kaki*) seeds for water purification. Initially, raw persimmon seeds were collected, thoroughly washed, dried, and crushed to obtain a fine powder. To enhance their adsorption capabilities, the seed powder underwent chemical activation using acidic treatment, which helped to increase surface area and expose functional groups such as carboxyl, hydroxyl, and phenolic groups. The experimental setup included the preparation of aqueous solutions contaminated with known concentrations of heavy metals (lead and copper) and organic pollutants (phenol). Batch adsorption experiments were carried out under controlled laboratory conditions, varying key parameters such as pH, contact time, and adsorbent dosage. The concentration of pollutants before and after treatment was measured using spectrophotometric and atomic absorption techniques to assess removal efficiency. Adsorption isotherms were modeled using Langmuir and Freundlich equations, while kinetic studies helped determine the rate and

mechanism of sorption. Comparative tests were also conducted using other common biosorbents including mango, avocado, guava seeds, and wood-based materials to benchmark the performance of persimmon seeds. The effectiveness of each biosorbent was evaluated and statistically analyzed using standard deviation and reproducibility tests to ensure reliability. The overall methodology ensured both the reproducibility of results and their relevance to practical water purification applications, aligning with environmental safety standards and regulatory frameworks established in Uzbekistan. This structured experimental design enabled the identification of persimmon seeds as a highly effective and eco-friendly biosorbent for removing hazardous pollutants from water.

Result and Discussion

In recent decades, many countries around the world have been actively researching the use of natural and biological materials as alternative sorbents for cleaning waste and drinking water. This is due to both economic and environmental considerations: such materials are cheap, biodegradable and often represent waste from the agro-industrial complex, which allows solving two problems simultaneously - water purification and disposal of organic waste (Foo & Hameed, 2010).

#Many countries in Asia and Latin America have conducted studies on the use of mango, avocado, olive and other fruit seeds as sorbents. For example, in India, mango seeds were studied as an adsorbent for removing heavy metals, including copper, zinc and lead (Ogunleye et al, 2021). Treatment with acid or alkali significantly increased their sorption capacity. Similar results were obtained in a study on the use of avocado seeds in Mexico, where they showed high efficiency in removing dyes and phenols from wastewater (Okoro & Egodigwe, 2020).

The European Union is actively promoting Zero Waste programs and circular economy principles, which place great emphasis on the reuse of biological waste. In Poland and Germany, studies have been conducted on the use of granulated natural sorbents based on wood and fruit residues. Their high adsorption capacity and suitability for industrial scaling have been proven (Ilyin, 2020) (Korneev, 2022).

In African countries such as Nigeria and Kenya, where there is an acute shortage of clean water, inexpensive purification methods are being actively developed. For example, Nigerian scientists have studied the effectiveness of crushed persimmon and guava seeds as a filter material, showing good results in removing chromium and other heavy metals (Nwabanne & Igbokwe, 2012).

Many projects supported by organizations such as UNESCO, the World Bank and the UN Environment Programme include components for the introduction of natural sorbents into local water treatment systems. These projects are aimed at supporting sustainable water use, especially in developing countries.

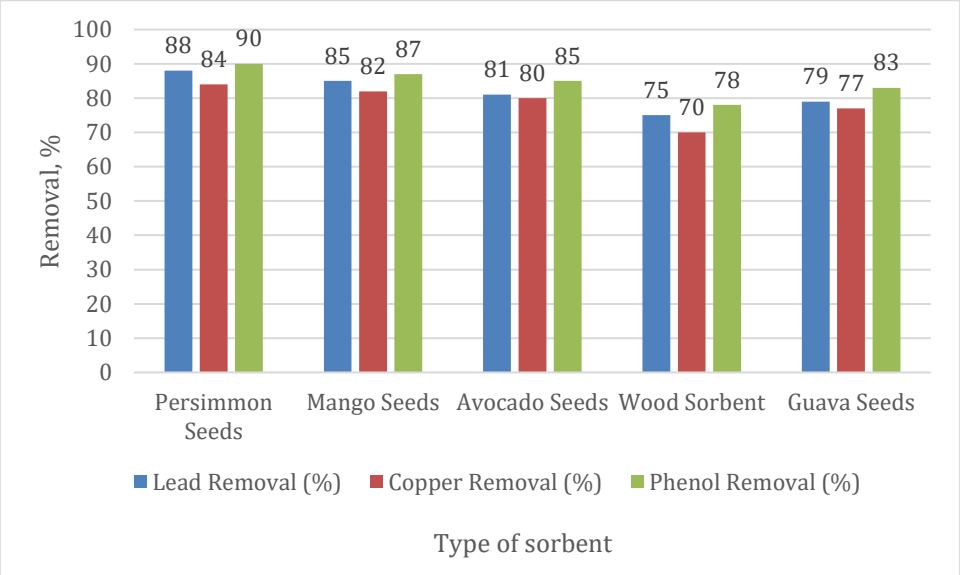

Figure 1. Efficiency of various sorbents in removing lead, copper and phenol from solutions

The bar chart compares five types of sorbents for their removal efficiency of three pollutants: lead (orange bars), copper (yellow bars), and phenol (green bars). The sorbents include persimmon pits, mango pits, avocado seeds, wood sorbent, and guava pits.

- Persimmon seeds showed the highest efficiency in all three indicators: 88% (lead), 84% (copper), 90% (phenol).
- Mango kernels and avocado seeds also showed high efficiency, especially in phenol removal (87% and 85%, respectively).
- The wood sorbent was the least effective, especially in removing copper (70%).
- Guava seeds showed balanced results with the highest efficiency in phenol removal (83%).

The diagram allows us to evaluate the potential of organic waste as effective and environmentally friendly sorbents for wastewater treatment. Thus, international experience confirms the potential of using agricultural waste, including persimmon pits, as effective, economically feasible and environmentally safe adsorbents. These practices can be adapted in Uzbekistan, taking into account local raw material potential and climatic conditions (Akhmedov, 2020) (Korneev, 2022) (Korneev, 2021).

Conclusion

The study conclusively demonstrated that persimmon seeds (Diospyros kaki), particularly after activation, possess high sorption capacities for removing hazardous pollutants such as lead, copper, and phenol from aqueous solutions, achieving removal efficiencies of up to 90%. These findings underscore the viability of using agricultural waste as an effective, low-cost, and environmentally sustainable alternative to conventional water purification technologies.

The superior performance of persimmon seeds compared to other natural biosorbents highlights their potential for broad application in both domestic and industrial water treatment systems, especially under acidic conditions. These results align with Uzbekistan's environmental policies promoting green technologies and support the integration of biosorbents into national water management strategies. The implications of this research extend to reducing organic waste, lowering treatment costs, and contributing to the circular economy. However, further studies are recommended to expand the range of target pollutants, optimize activation techniques, and explore the scalability of the process for real-world applications. Additionally, interdisciplinary collaboration and international funding can facilitate the development and implementation of innovative biosorption systems based on local agricultural by-products.

Recommendations

1. Industrial implementation: It is recommended to conduct pilot projects on the use of crushed and activated persimmon seeds in local wastewater and drinking water treatment systems at food and chemical industry enterprises.
2. Support at the state level: It is necessary to include in environmental and water management programs components for the development of technologies using natural sorbents and the creation of mechanisms to support such innovations at the legislative level.
3. Expanding the scope of research: It is recommended to expand the range of pollutants studied (e.g. petroleum products, microplastics, pharmaceuticals) and adapt seed activation methods to improve their effectiveness.
4. Use of agricultural waste: It is necessary to develop infrastructure for the collection, processing and disposal of organic waste (fruit pits, peels, etc.) for their further use in water purification.
5. International cooperation: It is advisable to attract grant funds and participate in international programs (UNDP, GEF, World Bank) aimed at introducing environmentally friendly water purification technologies.
6. Educational and scientific programs: Inclusion of the topic of natural sorbents in educational courses of universities, as well as support for research initiatives of students and postgraduates in the field of sustainable water purification.

Thus, natural biosorbents based on persimmon seeds represent a promising direction for the development of environmentally friendly water purification technologies, combining efficiency, availability and sustainability.

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