Assessment of Utilisation of Orange Peel Wastes for Preparation Of Eco-Friendly Adsorbent for Water Purification

Dr. Seema Agarwal[1], Rashmi Tripathi[2], Kanika Jain[2]

1. **HOD and Assistant Professor in Ram Chameli Chadha Vishwas Girls College, Department of Chemistry from C.C.S. University, Meerut, U.P.**
2. **M.Sc. students of Ram Chameli Chadha Vishwas Girls College, Department of Chemistry from C.C.S. University, Meerut, U.P.**

Corresponding author:
Dr. Seema Agarwal, HOD and Assistant professor in Ram Chameli Chadha Vishwas Girls College, Department of chemistry from C.C.S University, Meerut, U.P.
Seemakhilesh.agarwal@gmail.com, Ph no.9910562672

Abstract

The increasing contamination of water resources by heavy metals and organic pollutants has become a serious environmental concern. In this study, orange peel waste, an abundant agricultural by-product, was investigated as a low-cost and eco-friendly adsorbent for water purification. The dried and chemically modified orange peel was used to remove metal ions and dye contaminants from aqueous solutions. Batch adsorption experiments were conducted to study the effect of contact time, pH, adsorbent dose, and initial pollutant concentration. The results showed that orange peel exhibited significant adsorption capacity, due to the presence of functional groups such as carboxyl groups, hydroxyl groups, and pectin-based structures.The maximum adsorption was observed under slightly acidic conditions. The study demonstrates that orange peel waste can be effectively used as a sustainable material for wastewater treatment applications. Furthermore, the study highlights the potential of converting fruit waste into value-added materials, thereby supporting circular economy principles and reducing the environmental burden caused by agricultural residues. The simple preparation method and cost-effectiveness of orange peel adsorbent make it highly suitable for large-scale wastewater treatment applications in developing regions. This approach not only addresses water pollution but also promotes sustainable waste management and green chemistry practices.

Keywords: Orange peel, adsorption, wastewater treatment, heavy metals, bio-adsorbent, green chemistry.


UTILISATION OF ORANGE PEEL WASTES FOR PREPARATION OF ECO-FRIENDLY ADSORBENT FOR WATER PURIFICATION
ABSTRACT – VISUAL SUMMARY
1. BACKGROUND / PROBLEM
2. OBJECTIVE
3. ADSORBENT: ORANGE PEEL
4. METHODOLOGY: PREPARATION OF ORANGE PEEL ADSORBENT
5. ADSORPTION MECHANISM
6. KEY FINDINGS
7. IMPACT / SIGNIFICANCE
8. KEYWORDS

Fig. (1)

Introduction

Water pollution has become one of the most serious environmental problems in the modern world due to rapid industrialization, urbanization, and agricultural activities. Industrial effluents containing heavy metals, dyes, and toxic organic compounds are continuously discharged into water bodies, leading to severe ecological imbalances and health hazards. According to World Health Organization reports, contaminated water is responsible for several diseases affecting millions of people globally.

Conventional water treatment technologies such as chemical precipitation, ion exchange, membrane filtration, and activated carbon adsorption have been widely used. However, many of these methods are expensive and generate secondary waste. Therefore, researchers are increasingly focusing on low-cost, eco-friendly, and sustainable materials for wastewater treatment. In this context, adsorption using agricultural waste has emerged as a promising alternative.

Several recent researchers have made significant contributions to this field. **Salih et al. (2024)** reported that agricultural waste-based biosorbents show high efficiency for heavy metal removal due to their functional groups and porous structure. Similarly, **Rahman et al. (2023)**demonstrated that natural biomass materials are highly effective and sustainable alternatives for wastewater purification. **Afolabi and Musonge (2023)** investigated orange peel biochar and reported strong adsorption capacity for Cu^{2+} and Pb^{2+} ions through ion exchange and surface complexation mechanisms. These recent studies strongly support the use of biosorbents in environmental remediation.

Among various agricultural wastes, citrus fruit peels have gained considerable attention. **Hua et al. (2023)** studied modified orange peel and reported efficient removal of dye pollutants due to enhanced surface area and functional group activation. Orange peel, in particular, is rich in cellulose, hemicellulose, pectin, and lignin, which provide active binding sites for adsorption. The presence of carboxyl (-COOH) and hydroxyl (-OH) groups enhances its ability to interact with metal ions and dye molecules.

Furthermore, **El-Saied et al. (2022)** highlighted that chemical modification of agricultural waste significantly improves adsorption capacity by increasing surface area and exposing active functional groups. Similarly, **Islam et al. (2022)** reported that orange peel-based adsorbents effectively remove heavy metals from wastewater under optimized experimental conditions

In **2021**, **Michael-Igolima et al. (2021)** demonstrated that modified orange peel shows improved adsorption performance due to increased porosity and surface activation. In **2020**, **Chowdhury et al. (2020)** emphasized that agricultural waste materials are cost-effective and sustainable alternatives to commercial activated carbon for wastewater treatment applications.

Therefore, this study focuses on the utilization of orange peel waste as an eco-friendly adsorbent for the removal of contaminants from water. It aims to explore its efficiency, optimize adsorption conditions, and contribute to the development of sustainable wastewater treatment technologies in line with green chemistry principles.

In addition to its chemical composition, the surface morphology of orange peel also plays an important role in adsorption efficiency. The porous and fibrous structure increases the surface area available for pollutant interaction, thereby enhancing the uptake of contaminants from aqueous solutions. When subjected to physical or chemical activation, the number of active binding sites further increases, improving the overall adsorption capacity. This makes orange peel a promising biosorbent not only in its raw form but also in modified.

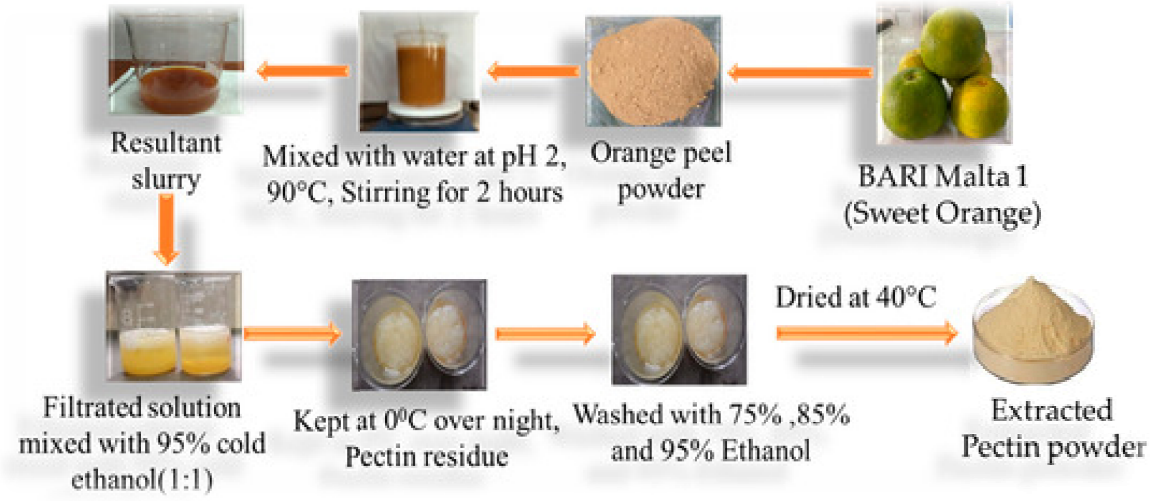

Fig.(2)

Recent studies have also focused on the role of functional group modification to improve adsorption performance. Treatments using acids, bases, or thermal processes help in exposing more active sites and removing unwanted impurities from the biomass surface. Such modifications increase the affinity of orange peel for metal ions and organic pollutants, making it more efficient in wastewater treatment applications.

From an environmental perspective, the utilization of orange peel waste also addresses the issue of solid waste management. Large quantities of citrus waste generated from juice industries and domestic use often end up in landfills, contributing to environmental pollution. Converting this waste into a useful adsorbent provides a dual benefit of waste valorization and water purification. This aligns with the principles of sustainable development and circular economy, where waste materials are reused to create value-added products.

Therefore, the present work focuses on exploring the orange peel as a low-cost, renewable, and efficient biosorbent for water purification. It emphasizes its potential application in removing pollutants from wastewater and highlights its importance as an alternative to expensive conventional adsorbents in environmental remediation processes.

Future Aspects

The utilization of orange peel as a biosorbent opens several promising directions for future research in wastewater treatment and green chemistry. One key area is the enhancement of adsorption efficiency through advanced modification techniques. Future studies could focus on converting orange peel into activated carbon or nano-composite materials by using chemical activation, thermal treatment, or metal oxide incorporation. These modifications are expected to significantly increase surface area and adsorption capacity.

Another important direction is the investigation of continuous flow system rather than batch experiments.Asmost present studies are laboratorybased, scaling up the process to column studies and real wastewater treatment plants is necessary to evaluate its industrial applicability. Furthermore, the regeneration and reusability of orange peel adsorbent should also be explored in detail to make the process more economical and sustainable.

In addition, future research can explore the application of orange peel in removing a wider range of pollutants, such as pharmaceuticals, pesticides, and emerging contaminants. Integrating orange peel-based adsorbents with other treatment methods like membrane filtration or photocatalysis may further improve overall water purification efficiency. These advancements will aid in developing cost-effective and environmentally friendly wastewater treatment technologies.

Conclusion

The present study demonstrates that orange peel waste is an effective, economical, and eco-friendly biosorbent for the removal of pollutants from aqueous solutions. The presence of functional groups such as hydroxyl groups and carboxyl groups, along with its porous structure, contributes significantly to its adsorption capacity. The results indicate that orange peel can successfully adsorb the metal ions and dyes molecules under optimized experimental conditions.

This study also highlights the importance of repurposing agricultural waste materials for environmental remediation. The conversion of orange peel waste into a valuable adsorbent is not only helps in reducing solid waste disposal problems but also provide a sustainable solution for wastewater treatment. “It supports the principles of green chemistry and circular economy by promoting waste-to-wealth conversion”.

In conclusion, orange peel shows strong potential as a low-cost alternative to conventional adsorbents like commercial activated carbon. With further modification and large-scale application studies, it can play an important role in developing sustainable and efficient water purification systems in the future.

References

1.**Salih, S.; et al. (2024).** Agricultural waste-derived biosorbents for heavy metal removal from wastewater: A review. *Environmental Pollution and Management Journal*, 2024.

2.**Kumar, A.; Sharma, R. (2024).** Recent advances in agricultural waste-based biosorbents for wastewater treatment. *Journal of Cleaner Production*, 2024.

3.**Rahman, A.; et al. (2023).** Biosorption of heavy metals using natural biomass materials: A sustainable approach. *Journal of Environmental Chemical Engineering*, 2023.

4.**Afolabi, F. O.; Musonge, P. (2023).** Orange peel biochar for adsorption of Cu^{2+} and Pb^{2+} ions from aqueous solutions. *Molecules*, 28, 2023.

5.**Hua, Z.; et al. (2023).** Modified orange peel biochar for efficient dye removal from wastewater. *RSC Advances*, 2023.

6.**Praipipat, P.; et al. (2023).** Enhanced lead adsorption using chemically modified orange peel biosorbent. *Scientific Reports*, 2023.

7.**Singh, PGupta, V. K. (2023).** Citrus peel-derived adsorbents for removal of heavy metals from aqueous solutions. *Environmental Research*, 2023.

8.**Wang, S.; Li, J. (2023).** Orange peel bioadsorbents for removal of dyes and toxic metals: A review. *Chemical Engineering Journal*, 2023.

9.**El-Saied, M.; et al. (2022).** Adsorption of heavy metals using agricultural waste-based hydrochar materials. *Biomass Conversion and Biorefinery*, 2022.

10.**Gómez-Aguilar, L.; et al. (2022).** Removal of toxic metal ions using fruit peel biosorbents. *Journal of Environmental Management*, 2022.

11.**Islam, N.; et al. (2022).** Removal of Cu^{2+} and Pb^{2+} using orange peel biomass: Kinetic and equilibrium studies. *Applied Water Science*, 2022.

12.**Ahmed, M.; et al. (2022).** Biosorption of heavy metals using fruit waste biomass: Kinetic and equilibrium studies. *Journal of Hazardous Materials Advances*, 2022.

13.**Patel, H.; Shah, M. (2021).** Low-cost agricultural waste adsorbents for wastewaterremediation: A review. *Environmental Technology & Innovation*, 2021.

14.**Michael-Igolima, U.; et al. (2021).** Modified orange peel as an efficient biosorbent for wastewater treatment. *Environmental Science and Pollution Research*, 2021.

15.**Chowdhury, Z. Z.; et al. (2020).** Agricultural waste as low-cost adsorbents for wastewater treatment: A review. *Journal of Cleaner Production*, 2020.