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PREPARATION OF MAGNETIC Fe₃O₄ MODIFIED WITH CARBON DOTS DERIVED FROM ORANGE PEELS EXTRACT AND ITS APPLICATION IN Ni²⁺ ADSORPTION

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Abstract. This study explores the development of carbon dots derived from orange peel for surface modification of Fe₃O₄ magnetic nanoparticles, with application in Ni²⁺ ion adsorption. The nanocomposite was characterized by DLS (Dynamic Light Scattering), revealing an average particle size distribution of 60 nm, and FTIR spectroscopy, which confirmed successful functionalization with orange peel-derived carbon dots through characteristic organic groups. Preliminary adsorption tests using UV-Vis spectroscopy demonstrated the material's effectiveness in Ni²⁺ removal from aqueous solutions. The orange peel carbon dot modification enhanced adsorption capacity compared to unmodified Fe₃O₄, attributed to increased surface functional groups and improved dispersion stability.

This work presents a green synthesis approach utilizing agricultural waste for water purification nanomaterials. While DLS provided essential size characterization, and further studies could explore the crystalline structure and adsorption kinetics in more detail.

Key words: Fe₃O₄ orange peels, carbon dots, DLS size analysis, FTIR confirmation, Eco-friendly advantage.

Introduction. Magnetic nanomaterials, particularly Fe₃O₄ (magnetite) nanoparticles, have attracted significant attention in recent years due to their high magnetic susceptibility, chemical stability, and large surface area [1]. These nanoparticles are effectively used in adsorption, catalysis, biomedicine, and environmental remediation. However, the tendency of Fe₃O₄ nanoparticles to aggregate and their chemical instability limit their practical applications [2, 3]. Therefore, surface modification with various natural materials, including biological sources such as orange peel extract, has emerged as a promising approach to enhance nanoparticle stability and improve their functional properties [4]. Orange peel contains abundant polyphenols, flavonoids, and organic acids that can form complexes on the Fe₃O₄ surface, improving its dispersion and adsorption capacity [5-7]. These modified nanomaterials are particularly effective in removing heavy metals, especially Ni²⁺ ions, from aqueous environments [8-10]. The high toxicity and negative environmental impact of Ni²⁺ ions make their removal from wastewater a critical challenge [11].

This study investigates the synthesis method, morphological and chemical characteristics of orange peel-modified Fe₃O₄ nanoparticles, as well as their adsorption capacity for Ni²⁺ ions. The results demonstrate the potential of these nanocomposites

as efficient and eco-friendly materials for heavy metal removal applications.

Research Methodology. Initially, orange peel powder is washed several times with distilled water to remove dust and excess substances and then finely ground. The peel is dried for 10 days in a place protected from direct sunlight. A certain portion of the dried peel pieces is soaked in 100 ml of 96% ethanol for 24 hours. Then it is treated with ultrasound for 10 minutes. The resulting extract is filtered and placed in a high-temperature resistant autoclave. The autoclave is placed in a hydrothermal reactor and kept in a muffle furnace at 180°C for 4 hours. The carbon dots obtained from the hydrothermal reactor after cooling to room temperature are centrifuged and filtered.

For the modification process, a certain amount of prepared Fe₃O₄ magnetic nanoparticles is placed in a beaker with freshly synthesized carbon dots and processed in a magnetic stirrer at 650 rpm at 40°C for 2 hours. To remove unmodified substances, the product is washed several times with water and ethanol. The final product is easily separated using an external magnetic field and dried (Figure 1).

Results and Discussion. The particle size distribution of the product was examined using dynamic light scattering (DLS) method. The analysis revealed that 61% of the particles were approximately 60 nm in size (Figure 2).

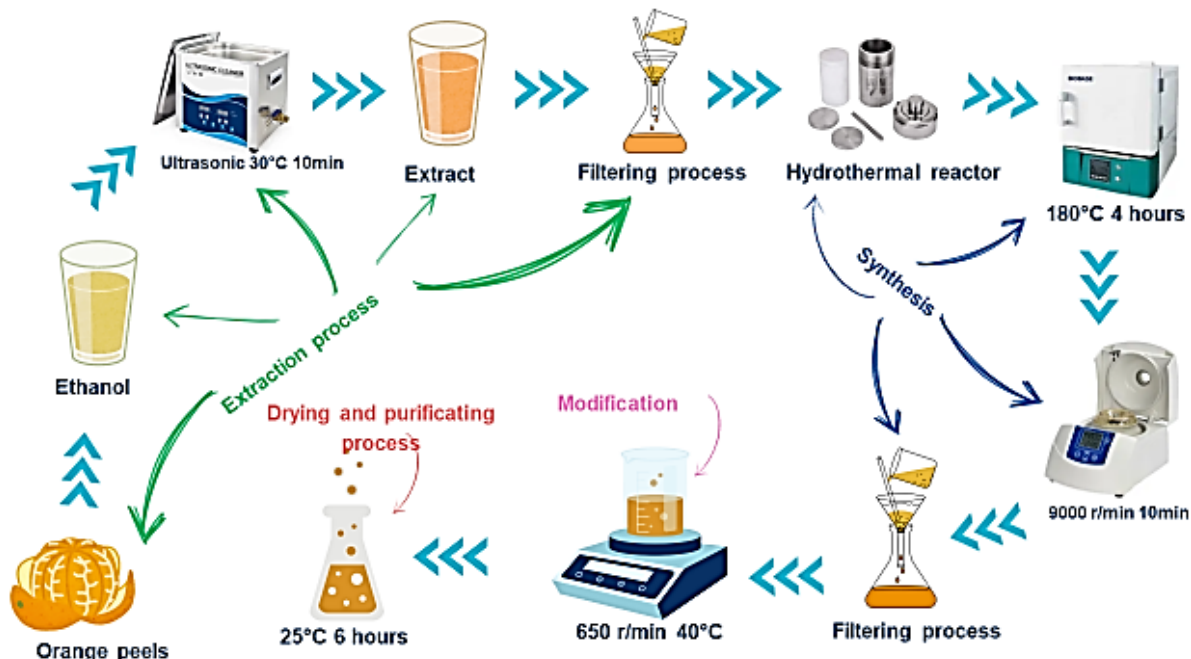


Figure 1. Synthesis and modification process

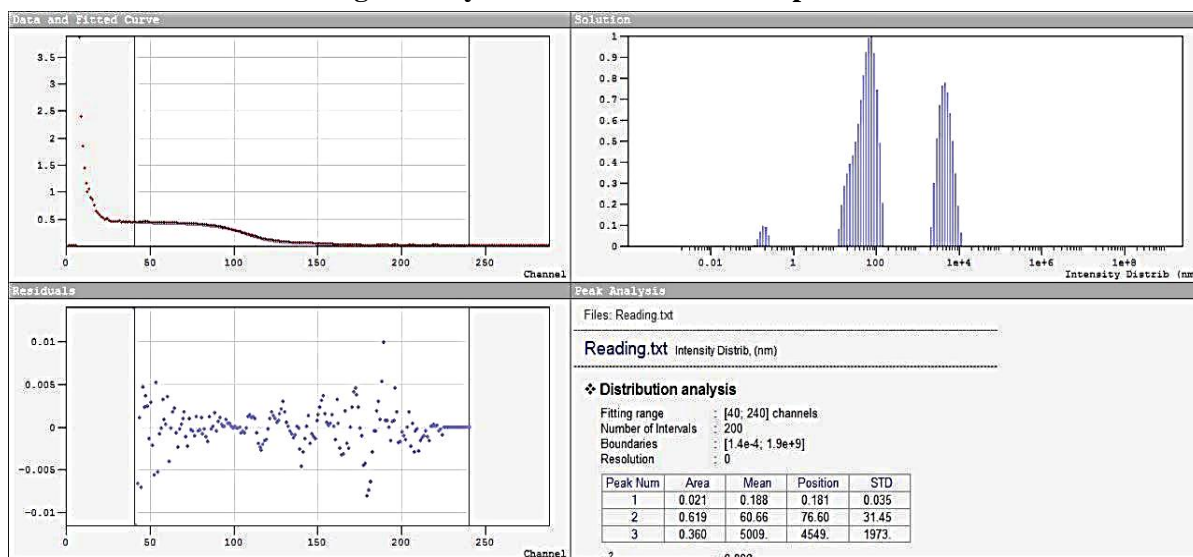


Figure 2. Dynamic light scattering (DLS) analysis of the obtained magnetic nanoparticles

The FTIR analysis of Fe_3O_4 magnetic nanoparticles and the obtained Fe_3O_4/OP showed absorptions in the regions of OH 3475 cm^{-1} , NH_2 3265 cm^{-1} , COOH 1650 cm^{-1} , Ar 1510 cm^{-1} , CH_3 1240 cm^{-1} , C-O-C 1170 cm^{-1} , Fe-O 580 cm^{-1} (Figure 3).

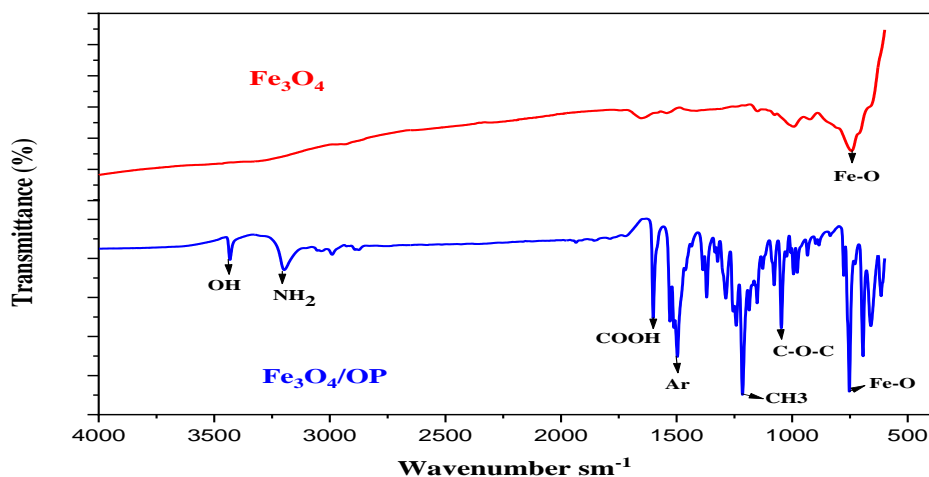


Figure 3. FTIR Spectroscopy Analysis of Fe_3O_4 and Fe_3O_4/OP Nanocomposites

The obtained product was conditionally named $\text{Fe}_3\text{O}_4/\text{OP}$. The heavy metal adsorption property of $\text{Fe}_3\text{O}_4/\text{OP}$ magnetic nanoparticles was studied using NiCl_2 standard solutions of various concentrations (Fig. 4).

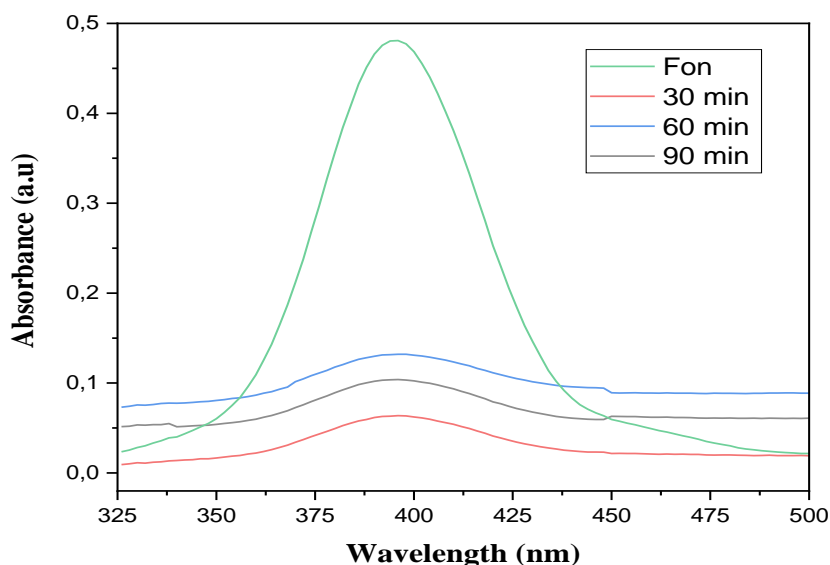


Figure 4. UV/Vis spectrophotometric analysis of Ni^{2+} adsorption

50 mg of the obtained magnetic nanoparticles were added to 50 ml of NiCl_2 standard solution. As a result, it was observed that the adsorption was intense in the first 30 minutes, and after 90 minutes the adsorption remained unchanged. To increase the adsorption efficiency, the pH of the solution, concentration, and temperature are also important factors.

Conclusion. In conclusion, Fe_3O_4 magnetic nanoparticles modified with carbon dots derived

from orange peel are an environmentally friendly adsorbent. In particular, it shows important indicators in the adsorption of Ni^{2+} . The use of magnetic adsorbents in the removal of heavy metals in wastewater is preferred over other adsorbents due to its ease of use. Because after adsorption, the adsorbent can be easily separated from the environment using an external magnetic field.

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G'ulomova I.B., Mahkamov M.A., Islomov M.M. Karboksimetilkraxmal asosidagi bioparchalanuvchi polimer plyonkalar va ularning xossalari	125
Umrzoqov A.T., Muxiddinov B.F., Ikramov A., Vapoyev H.M., Qodirov S.M. Kompozit katalizatorlar ishtirokida atsetaldegidning ammiak bilan kondensatsiylanishi	129
Eshbaeva U.J. Tarkibida yelimlovchi moddalar bo'lgan qog'ozning bosma xossalarini tadqiq qilish	134
Хамдамова Ч.Х., Сайфиева П.О., Очилов Э.А., Абед Н.С., Камолов Т.О. Исследование влияния параметров магнитного сепаратора на эффективность извлечения магнитной фракции	137
Амонова М.М. Saproel asosidagi sorbentlarning fazaviy tahlili: rentgenodifraksiya usulida baholash	140
Яхшиева З.З., Асророва З. Методика определения ионов Fe(III) в мясных продуктах	143
Бакахонов А.А., Яхшиева З.З., Султонов М.М. Карбоплатинни электрохимический анализ килиш	145

6. Проблемные обзоры

Исаходжаева Н.А. Анализ и исследование свойств композиционных материалов и правила адаптивного конструирования	149
Озодова Ш.О. Автоматизация метрологических измерений	151
Сайдалиева У.Р. Исследование свойств композиционных материалов, используемых в целлюлозных головных уборах	154
Очиллов Э.А., Юсупов О.Г., Холбозорова Д.Н., Сайдуллаева К.А., Абдурахимов К.Г., Хушвактова У.А. Исследование механизма процесса выщелачивания огарка соляной кислотой	156
Турганбаев. Б.Б., Калбаев Б.А., Нажимов Ж.Б., Мамутов У.Б., Танатаров О.Р. Исследование возможностей применения базальта Шехжелинского месторождения в производстве строительных материалов	158
Очилдиев К.Т., Мухаметджанова Ш.А., Маткаримов С.Т., Носирхужаев С.К. Исследования по улучшению способа обеднения шлаков медного производства, применяемые в процессе плавления в отражательной печи	161
Parmonov G., Parmonov S. "O'zbekiston texnologik metallar kombinati" AJ qoshidagi Nodir metallar va qattiq qotishmalar ishlab chiqarish zavodi volfram texnogen chiqindilarini tahlil qilish	165
Xandamov D.A., Xonqulov Sh.B., Bekmirzayev A.Sh., Xandamova D.K., Doniyorov S.A., Xudoyberdiyev A.I. Adsorbsiya muvozanat izotermalarining nazariy asoslari va tahlili	168
Курязов З.М., Кадырова З.Р., Эминов А.М., Азимов Х.Э. Альтернативный источник глинистого сырья-илистых отложений водохранилищ для производства керамических материалов	171
Yoqubov O.M. "Olmaliq KMK" AJda metall ishlab chiqarish texnogen xomashyolarining ahamiyati	174
Абдувалиева К.Х. К вопросу интенсификации технологии извлечения металлов платиновой группы	178
Egamberdiyeva Sh.U., Berdimurodov E.T., Akbarov Kh.I. Synthesis of carbon dot from pomegranate peel waste and its modification with Fe ₃ O ₄ magnetic nanoparticle	180
Daminov T.Z., Maxmarejabov D.B. Angren ko'mir konidan olingan qo'ng'ir ko'mir va kaolinli gil namunalarning moddiy tarkibi o'rganish	183
Кулдеев Е.И., Негматов С.С. Диатомиты и потенциал их использования.....	186
Rasulov A.A., Berdimurodov E.T., Akbarov Kh.I. Preparation of magnetic Fe ₃ O ₄ modified with carbon dots derived from orange peels extract and its application in Ni ²⁺ adsorption	189
Ruzmetov A.Kh., Ibragimov A.B., Atajanov B.A. Crystal structure and UV-Vis spectroscopic correlation of [triacqua-μ ₃ -oxido-hexa(3-hydroxybenzoato)triiron(III)] chloride dihydrate	192
Рахимов Х.Ю., Юсупходжаева Э.Н., Аюбова И.Х., Халматова Н.Г. Магистрал газ кувурларини коррозиядан химия килиш йўллари	195
Akbarova Z.O. Application of zardozi embroidery technique in clothing and methods for its improvement	197