ISNN:2181-1296

SHAROF RASHIDOV NOMIDAGI
SAMARQAND DAVLAT UNIVERSITETI

САМАРКАНДСКИЙ ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ ИМЕНИ ШАРОФА РАШИДОВА

SAMARKAND STATE UNIVERSITY NAMED
AFTER SHAROF RASHIDOV

ILMIY AXBOROTNOMA

НАУЧНЫЙ ВЕСТНИК
SCIENTIFIC JOURNAL

ANIQ VA TABIIY FANLAR SERIYASI

Matematika, Mexanika, Informatika
Fizika, Kimyo, Biologiya, Geografiya

№ 1/2 (155)
2026

ISSN 2181-1296

ILMIY AXBOROTNOMA

НАУЧНЫЙ ВЕСТНИК SCIENTIFIC JOURNAL

2026-yil, 1-son (155/2) ANIQ VA TABIIY FANLAR SERIYASI

Matematika, Mexanika, Informatika, Fizika, Kimyo, Biologiya, Geografiya

Samarqand viloyat matbuot boshqarmasida ro‘yxatdan o‘tish tartibi 09-25.
Jurnal 1999-yildan chop qilina boshlagan va OAK ro‘yxatiga kiritilgan.

BOSH MUHARRIR **R. I. XALMURADOV, t.f.d., professor**
BOSH MUHARRIR O‘RINBOSARLARI: **H.A. XUSHVAQTOV, f-m.f.d., dotsent**

TAHRIRIYAT KENGASHI:

Sh.A.Alimov	- O‘zFA akademigi	**M.X.Ashurov**	- O‘zFA akademigi
S.N.Lakayev	- O‘zFA akademigi (SamDU)	**B.J.Axmedov**	- O‘zFA akademigi
M.M.Kamilov	- O‘zFA akademigi	**Q.G‘.G‘ulomov**	- O‘zFA akademigi
A.G.Yagola	- Moskva davlat universiteti professori (Rossiya)	**A.A.Zaxidov**	-Texas Nanotexnologiya instituti professori (AQSh)
Alberto Del Bimbo	-Florensiya universiteti professori (Italiya)	**N.B. Ferapontov**	- Moskva davlat universiteti professori (Rossiya)
Sh.Tugizov	-Kaliforniya universiteti professori (AQSh)	**V.L.Popov**	-Berlin texnika universiteti professori (Germaniya)
A.S.Soleev	- f.-m.f.d., professor (SamDU)	**N.F.Bunkin**	- Moskva davlat texnika universiteti professori (Rossiya)
I.A.Ikromov	- f.-m.f.d., professor (SamDU)	**Haji Akber Aisa**	-Xinjiang tibbiyot universiteti professori (Xitoy)
B.X.Xo‘jayarov	- f.-m.f.d., professor (SamDU)	**E. A. Abduraxmonov**	- k.f.d., professor (SamDU)
L.Sabirov	-f.-m.f.d., professor (SamDU)	**N. K. Muxamadiyev**	- k.f.d., professor (SamDU)
A.Jumaboyev	-f.-m.f.d., professor (SamDU)	**L. A. Bulavin**	- Kiev milliy universiteti
X.Bozorov	-k.f.d., professor (SamDU)	**X. Q. Xaydarov**	- b.f.d., professor (SamDU)
O.Q.Quvondiqov	-f.-m.f.d. professor (SamDU)	**Z. I. Izzatullayev**	- b.f.d., professor (SamDU)
A.Z.Xasanov	-f.-m.f.d. professor (SamDU)	**A.B.Hasanov**	-tex.f.d., professor (SamDU)
Muhammad Suzuri bin Hitam	- Terengganu universiteti professori (Malayziya)	**Sh. T. Xoliqulov**	- q.-x.f.d., professor (SamDU)
K.D.Kuliyev	- f.-m.f .n. professor (SamDU)	**S. B. Abbosov**	- g.f.d., professor (SamDU)
A.M.Xolxo‘jayev	-f.-m.f.d., professor (SamDU)	**M.E. Mo‘minov**	-f.-m.f.d., professor (SamDU)
J.Abdullayev	-f.-m.f.d., professor (SamDU)	**I.I.Jumanov**	-tex.f.d., professor (SamDU)
A.R.Axatov	-tex.f.d., professor (SamDU)	**N.S.Mamatov**	-tex.f.d., professor (TIQXMMI)
D.B.Xursanov	- g.f.f.d., dotsent (SamDU)	**A.Sh.Yarmuxamedov**	-f-m.f.n., dotsent (SamDU)
F.Nazarov	-tex.f.d., dotsent (SamDU)	**X.S.Xaydarov**	-f-m.f.n., dotsent (SamDU)

Obuna indeksi – yakka tartibdagi obunachilar uchun **- 5583,**
tashkilot, korxonalar uchun **- 5584**

M U N D A R I J A
C O N T E N T S

№	Maqola nomi	Article title	Bet/ page
1.	Yuqori chastotali II-turdagi radio portlash spektral kuzatuvlaridan foydalanib magnit maydon kuchini baholash **Pulatov D., Mirtoshev Z.**	Estimation Of The Coronal Magnetic Field Strength Using High-Frequency Type Ii Radio Burst Observations **Pulatov D., Mirtoshev Z.**	**5-11**
2.	Rayxon (OCIMUM) o‘simligi efir moyi kimyoviy tarkibiga iqlim omillarining ta’sirini GX–MS usulida tadqiq etish **Siddikova Y., Saifullaeva Sh., Mukhamadiyev A., N.Fazlieva, Nayimova B., Muhamadiyev N.**	Study of the influence of climate factors on the chemical composition of basil (ocimum) essential oil using the GH–MS method **Siddikova Y., Saifullaeva Sh., Mukhamadiev A., N.Fazlieva, Nayimova B., Muhamadiev N.**	**12-20**
3.	Bentonitni montmorillonit bilan boyitishning samarali usullari va termal ishlov berishning kation almashinuvi quvvatiga ta'siri **Mamadoliev I., Abdikamalova A., Ruzieva S.**	Effective methods for bentonite enrichment with montmorillonite and the impact of thermal treatment on cation exchange capacity **Mamadoliev I., Abdikamalova A., Ruzieva S.**	**21-28**
4.	$KPbBr_3$ asosidagi peroled tuzilmalarida zaryad tashish mexanizmlari va energetik sathlarning moslashuvi **Rahmonova M., Muxamadiyev N.**	Charge transport mechanisms and energy level alignment in $KPbBr_3$ -based peroled structures **Rahmonova M., Mukhamadiev N.**	**29-36**
5.	*N*-(4-(((7-Nitroxinazolin-4-il) amino) metil)fenil) siklogeksankarboksamid sintezi **Gaybullaev Sh., Takhirov Y., Chao Niu, Bozorov Kh.**	Synthesis of N-(4-(((7-nitroquinazolin-4-YL) amino) methyl) phenyl) cyclohexanecarboxamide **Gaybullaev Sh., Takhirov Y., Chao Niu, Bozorov Kh.**	**37-41**
6.	3-brom-pirido[2,3-*d*]pirimidinonlarning sintezi **Khushnazarov Z., Turgunov D., Bozorov Kh.**	synthesis of 3-bromo-pyrido[2,3-d]pyrimidinones **Khushnazarov Z., Turgunov D., Bozorov Kh.**	**42-46**
7.	Zarrachalar tezlatkichlarida materiallarning aktivatsiyasi va radiatsion xavflar **Temirov J., Khasanov Sh., Safarov A., Karimberganova Q.**	Material activation and radiological hazards in particle accelerators **Temirov J., Khasanov Sh., Safarov A., Karimberganova Q.**	**47-57**
8.	Geoinformatsion dasturlar yordamida demografik atlaslar yaratishning afzalliklariga nazar **Tukhtamishev Sh., Khudoyarova Sh., Shirinboyev D.**	Advantages of creating demographic atlases using geoinformation software **Tukhtamishev Sh., Khudoyarova Sh., Shirinboev D.**	**58-62**
9.	Siklopropilatsetilen asosida atsetilen spirtlari sintezi, ularning nazariy energetik xarakteristikalari va nadfoksidaza oqsili (7U8G) bilan molekulyar birikish tahlili **Ziyadullaev M.E., Nurmanov S.E., Buriev F.Kh., Abdukhalikov F.J.**	Synthesis of acetylenic alcohols based on cyclopropylacetylene, their theoretical energetic characterization, and molecular docking analysis with nadph oxidase (7U8G) protein **Ziyadullaev M.E., Nurmanov S.E., Buriev F.Kh., Abdukhalikov F.J.**	**63-71**
10.	Tetratsiklik tieno[3,2-*d*]pirimidinonlarning siklooksigenaza-2 ingibitorlari sifatida *in silico* tadqiqi **Nasrullaev A., Buronov A., Gaybullaev Sh., Bozorov Kh.**	In silico evaluation of tetracyclic thieno[3,2-d]pyrimidinones as potential cyclooxygenase-2 inhibitors **Nasrullaev A., Buronov A., Gaybullaev Sh., Bozorov Kh.**	**72-76**
11.	H3PO4, KOH va ZnCl2 yordamida olingan faollashtirilgan ko‘mirning morfologik va strukturaviy xususiyatlarining qiyosiy tahlili **Ergasheva D., Mukhamadiyev A., Mukhamadiyev N., Uzokov J.**	Comparative analysis of the morphological and structural properties of activated carbon prepared using H_3PO_4, KOH, and $ZnCl_2$ **Ergasheva D., Mukhamadiev A., Mukhamadiev N., Uzokov J.**	**77-81**
12.	CO_2 NI quyosh nuri ta’sirida samarali konversiyalashni ta’minlovchi g-C_3N_4/$CoNi_2S_4$ geterotuzilmali nanomateriallar sintezi va fizik-kimyoviy xossalari **Samiev A., Nizamov U.N., Mirzaev Sh., Ruzimuradov O., Nasimov A.**	Synthesis and physicochemical properties of γ-C3N4/CoNi2S4 heterostructured anomaterials providing efficient conversion of CO2 under the influence of sunlight **Samiev A., Nizamov U.N., Mirzaev Sh., Ruzimuradov O., Nasimov A.**	**82-87**

№	Maqola nomi	Article title	Bet/ page
13.	Atrof muhitdagi ammiak mikrokensentratsiyasini monigitori uchun gibrid perovskit $MA_xFA_{1-x}PbI_3$ fluoressent sensori tayyorlash **Eshmuradova G.B., Tashpulatov Kh.Sh., Khursandov J.M., Normuradov O.U., Norboyev Q.M., Toshpulatov D.T.**	Preparation of hybride perovskite $MA_xFA_{1-x}PbI_3$-fluorescent sensor for the monitoring of ammonia microconcentration in environment **Eshmuradova G.B., Tashpulatov Kh.Sh., Khursandov J.M., Normuradov O.U., Norboev Q.M., Toshpulatov D.T.**	**88-92**
14.	Al^{3+} bilan modifikatsiyalangan shpinel tuzilishga ega $Li_{1.33}Al_XMn_{1.67-X}O_4$ ($0 \leq x < 0.7$) tarkibli adsorbentlarning zol-gel sintezi va fizik-kimyoviy xossalari **Begimkulova Sh.A., Nematova Sh.Sh., Baxriev I.S., Mirzaev Sh.E., Ruzimuradov O.N., Nasimov A.M.**	Sol-gel synthesis and physicochemical properties of adsorbents consisting of Al^{3+} modified spinel structure $LI_{1.33}Al_XMn_{1.67-X}O_4$ ($0 \leq X < 0.7$) **Begimkulova Sh.A., Nematova Sh.Sh., Baxriev I.S., Mirzaev Sh.E., Ruzimuradov O.N., Nasimov A.M.**	**93-99**
15.	CdCr2Se4 va CuCr4Se4 magnitli yarimo‘tkazgichda magnit-optik effektlar **Dosmurodov G.**, **Kurbaniyazov A.**, **Boboqambarova G.**	Magneto-optical effects in the magnetic semiconductor CdCr2Se4 AND CuCr4Se4 **Dosmurodov G.**, **Kurbaniyazov A.**, **Bobokambarova G.**	**100-104**
16.	Sophora lehmanni va Cicer mogoltavikum o‘simliklari yer ustki qismilarining flavonoidlari **Gafurov A.Zh, Botirov E. Kh.**	Flavonoids of aerial parts of sophora lehmannii and cicer mogoltavicum **Gafurov A.Zh, Botirov E. Kh.**	**105-109**
17.	Buxoro viloyatining balneologik resurslari va ularning aholi salomatligini yaxshilashdagi ahamiyati **Zaynutdinova D.K., Nematova Kh. Kh.**	Balneological resources of the bukhara region and their significance in improving public health **Zaynutdinova D.K., Nematova Kh. Kh.**	**110-116**
18.	Tabiiy cho‘kuvchan gruntlarni polimer-kompozitsion eritmalar bilan inyeksion mustahkamlash texnologiyasini matematik rejalashtirish **Bakhriyev N.F., Kholiqulov O.O., Nurmatova R.K.**	Mathematical planning of injection strengthening technology of natural collapsible soils using polymer-composite solutions **Bakhriyev N.F., Kholikulov O.O., Nurmatova R.K.**	**117-125**
19.	Adgezion kontaktlarda ishqalanish koeffitsiyentiga geometrik parametrlar hamda tashqi yuk ta’sirining tahlili **Bekmamatova G., Xoliqulov O., Tojinorov M.**	Analysis of geometric parameters and external load on the friction coefficient in adhesive contacts **Bekmamatova G., Xolikulov O., Tojinorov M.**	**126-131**
20.	Markaziy Osiyo iqlim sharoitida sorbsion sovutgichlardan biogaz komplekslari bilan simbiozda foydalanish istiqbollari **Abdusamiyev F., Bahriev S., Sattarov S.**	Prospects for using sorption refrigerators in symbiosis with biogas complexes in the climatic conditions of Central Asia **Abdusamiev F., Bahriev S., Sattarov S.**	**132-136**
21.	Maple tizimida algebraik ko’pxilliklarni ratsional parametrlashining nazariy asoslari va kompyuterda amalga oshirilishi **Usmonova N.**	Theoretical foundations and computer implementation of rational parameterization of algebraic manifolds in the maple system **Usmonova N.**	**137-142**
22.	$Fe_5Ga_6Gd_2YZr$ ko‘p komponentli kristallining element tarkibi va tebranish xossalarini rentgen-fluoresans (XRF) va raman spektroskopiyasi yordamida tadqiq etish **Nasirova N., Fayziyev Sh., Saidov Q., Qaxorova Sh., Sharipov M., Djuraev D.**	Investigation of the elemental composition and vibrational properties of the multicomponent crystal Fe5Ga6Gd2YZr using X-RAY fluorescence (XRF) and raman spectroscopy **Nasirova N., Fayziyev Sh., Saidov Q., Qaxorova Sh., Sharipov M., Djuraev D.**	**143-152**
23.	Xofp tipidagi tenglamalar sistemasi uchun Koshi masalasi **Erkinova D. A.**, **Imomnazarov Kh. Kh.**	Cauchy problem for a Hopf-type system **Erkinova D. A.**, **Imomnazarov Kh. Kh.**	**153-157**
24.	Ar va HCl izotopologlari o‘rtasida hosil bo‘lgan komplekslarning kvant-kimyoviy tahlili: AIM, RDG va NCI usullari yordamida solvatatsiya effektlarini o‘rganish **Khujamov U.**	Quantum-chemical analysis of complexes formed between Ar and HCL isotopologues: studying solvation effects using AIM, RDG, and NCI methods **Khujamov U.**	**158-167**

UDC: 661.183.2:544.723 https://doi.org/10.59251/2181-3973.2025.v1.138.1.3775

COMPARATIVE ANALYSIS OF THE MORPHOLOGICAL AND STRUCTURAL PROPERTIES OF ACTIVATED CARBON PREPARED USING H_3PO_4, KOH, AND $ZnCl_2$

D.Ergasheva, A.Mukhamadiyev, N.Mukhamadiyev, J.Uzokov
Samarkand State University named after Sharof Rashidov, Samarkand, Uzbekistan.

D.Ergasheva Samarkand State University named after Sharof Rashidov, Samarkand, Uzbekistan.

Received: 17.01.2026
Revised: 28.01.2026
Accepted: 14.02.2026
Published: 30.03.2026

Publisher: Samarkand State University named after Sharof Rashidov.

Abstract. In this study, activated carbon samples derived from walnut shells and chemically activated using H_3PO_4, KOH, and $ZnCl_2$ were comparatively evaluated in terms of their morphological features, pore development, and surface characteristics. The results obtained from scanning electron microscopy (SEM) revealed that the sample activated with H_3PO_4 exhibited a relatively uniform microporous structure. In contrast, the carbon produced using KOH demonstrated the formation of macro- and mesopores with a broad size distribution. Meanwhile, the $ZnCl_2$-activated sample was characterized predominantly by the development of a mesoporous framework. The findings confirm that the type of chemical activating agent plays a critical role in governing the structural organization and textural properties of nanoporous carbon-based sorbents.

Keywords: Activated carbon, walnut shell, H_3PO_4, KOH, $ZnCl_2$, scanning electron microscopy (SEM), morphology, porosity.

H3PO4, KOH va ZnCl2 yordamida olingan faollashtirilgan ko‘mirning morfologik va strukturaviy xususiyatlarining qiyosiy tahlili

Annotatsiya. Ushbu maqolada yong‘oq po‘stlog‘i asosida tayyorlangan faollashtirilgan ko‘mir namunalarining H_3PO_4, KOH va $ZnCl_2$ kabi kimyoviy faollashtiruvchi reagentlar yordamida olingan turlari morfologik tuzilishi, g‘ovaklik darajasi hamda sirt xossalari nuqtai nazaridan qiyosiy ravishda o‘rganildi. Skanerlovchi elektron mikroskopiya (SEM) tahlili natijalari H_3PO_4 bilan faollashtirilgan namunada nisbatan bir xil shakldagi mikrog‘ovak tuzilma shakllanganini ko‘rsatdi, KOH yordamida olingan namunada esa turli o‘lchamdagi makro va mezog‘ovak tuzilmalar kuzatildi. $ZnCl_2$ bilan faollashtirilgan ko‘mir namunalarida asosan mezog‘ovakli strukturaning hosil bo‘lishi aniqlandi. Olingan natijalar tanlangan faollashtiruvchi reagent turining nanog‘ovak sorbentlarning tuzilishi va tekstur xususiyatlarining shakllanishiga sezilarli darajada ta’sir ko‘rsatishini tasdiqlaydi.

Kalit so‘zlar: Faollashtirilgan ko‘mir, yong‘oq po‘stlog‘i, H_3PO_4, KOH, $ZnCl_2$, SEM, morfologiya, g‘ovaklik.

Сравнительный анализ морфологических и структурных свойств активированного угля, полученного с использованием H_3PO_4, koh и $ZnCl_2$

Аннотация. В данном исследовании образцы активированного угля, полученные из скорлупы грецкого ореха и химически активированные с использованием H_3PO_4, KOH и $ZnCl_2$, были сравнительно оценены с точки зрения их морфологических характеристик, развития пористой структуры и свойств поверхности. Результаты, полученные с

помощью сканирующей электронной микроскопии (SEM), показали, что образец, активированный H_3PO_4, обладает относительно однородной микропористой структурой. В отличие от этого, уголь, полученный с применением KOH, характеризовался формированием макро- и мезопор с широким распределением размеров. В то же время образец, активированный $ZnCl_2$, преимущественно отличался развитием мезопористой структуры. Полученные результаты подтверждают, что тип химического активирующего реагента играет ключевую роль в формировании структурной организации и текстурных свойств нанопористых углеродных сорбентов.

Ключевые слова: Активированный уголь, скорлупа грецкого ореха, H_3PO_4, KOH, $ZnCl_2$, сканирующая электронная микроскопия (SEM), морфология, пористость.

Introduction. Over the past two decades, the unsustainable and excessive exploitation of natural resources has contributed significantly to environmental degradation and the emergence of ecological imbalances within natural systems. The accelerated expansion of industrial activities along with ongoing urban development has significantly increased the emission of volatile organic compounds containing nitrogen-, sulfur-, and chlorine-based species, as well as pharmaceutical residues and agrochemical pollutants into the environment. Moreover, the intensification of agricultural operations has contributed to the rapid depletion of biomass resources, fossil energy sources, and freshwater supplies, which in turn disturbs natural ecosystems and affects vital biogeochemical cycles. At the same time, the growing accumulation of industrial and agricultural by-products has led to increased levels of contamination in air, soil, and water systems. The persistent discharge of both organic and inorganic pollutants into water bodies results in a decline in water quality, posing considerable threats to aquatic life and human health. Therefore, the development of environmentally sustainable materials capable of effectively eliminating hazardous contaminants has become a major focus of modern scientific research.

In recent years, activated carbon produced from renewable biomass precursors has been widely recognized as a promising sorbent for environmental protection applications. Owing to their chemical composition, degree of porosity, surface architecture, as well as adsorption and catalytic activity, porous nanomaterials are extensively utilized in thermal insulation coatings, alternative energy systems, catalysis, biomedicine, and as stationary phases in chromatographic separation processes. The increasing level of environmental contamination by heavy metal ions and organic pollutants has further intensified the demand for efficient sorbents derived from natural resources. Among such materials, activated carbon obtained from low-cost and renewable agricultural wastes, such as walnut shells, has gained particular attention as an environmentally friendly and highly efficient sorbent.

At present, the demand for such sorbent materials is steadily increasing in wastewater treatment, pollution control, and industrial waste management applications. Nevertheless, the synthesis of thermally stable and selective nanoporous sorbents suitable for chromatographic applications remains a significant scientific challenge. Therefore, in this study, nanoporous carbon sorbents with enhanced porosity and improved thermal stability were synthesized, and their morphological characteristics were systematically investigated. Chemical activating agents such as KOH, $ZnCl_2$, and H_3PO_4 were employed during the activation process, as they exert distinct influences on pore development, surface structure, and the overall textural properties of the resulting carbon materials. The surface morphology, pore size distribution, and structural heterogeneity of the prepared samples were analyzed using scanning electron microscopy (SEM) along with a comparative evaluation of the obtained materials.

Objective of the Study. The primary objective of this research is to comparatively investigate the surface morphology of activated carbon samples prepared using H_3PO_4, KOH, and $ZnCl_2$ through scanning electron microscopy (SEM), and to determine the influence of the type of activating agent on the pore structure and surface texture of the resulting materials.

Research Object and Methods. Activated carbon samples derived from walnut shells and chemically activated using H_3PO_4, KOH, and $ZnCl_2$ were selected as the object of this study. The prepared samples were analyzed at different magnification levels using scanning electron microscopy

(SEM) to visually evaluate their surface morphology and pore structure. During the sample preparation process, the drying and thermal treatment stages were strictly controlled, and a comparative analysis was conducted based on the obtained SEM images.

Results and discussion. The surface morphology of the obtained sorbent samples was examined using scanning electron microscopy (SEM). During the SEM analysis, the surface architecture of the samples, as well as the shape, distribution, and spatial arrangement of the pores, were visually assessed at different magnification levels. This technique enabled the evaluation of the degree of pore structure development, surface irregularities, and structural heterogeneity of the sorbent materials. Furthermore, the morphological variations induced by different chemical activating agents were comparatively analyzed. Based on the acquired micrographs, the influence of activation conditions on the formation of surface texture and pore structure of the sorbents was systematically evaluated.

Activated Carbon Prepared by H_3PO_4 Activation. SEM micrographs of the activated carbon prepared using H_3PO_4 revealed a relatively uniform surface morphology with the formation of an interconnected porous network. Phosphoric acid facilitates the thermochemical decomposition of lignin and cellulose components, thereby promoting the preservation of the carbon framework and the development of an enhanced porous structure. During this process, H_3PO_4 forms phosphorylated cross-linked bonds within the polymeric matrix, which contributes to the improved mechanical strength and thermal stability of the carbon structure. In addition, the release of volatile components during the activation process promotes the evolution of surface texture and the formation of well-developed pores. As a result, the uniform distribution of micropores in the produced carbon provides favorable conditions for adsorption processes. Such materials possess high surface energy and active functional groups, enabling the efficient adsorption of heavy metal ions as well as organic contaminants. The samples activated with H_3PO_4 are distinguished by their chemical stability and regeneration capability, making them promising sorbents for repeated use. The SEM image illustrating the surface morphology of the H_3PO_4-activated carbon is presented in Figure 1.

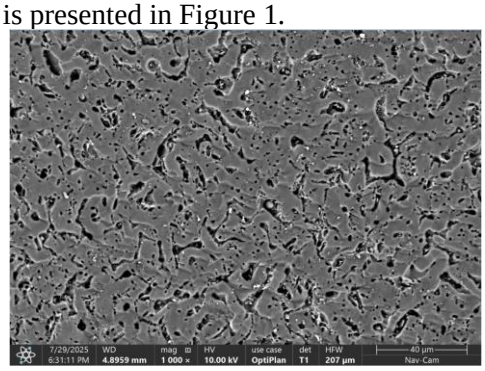


Figure 1. SEM image of activated carbon prepared using H_3PO_4 activation.

Activated Carbon Prepared by KOH Activation. KOH activation is considered one of the most effective physicochemical methods for the development of porous carbon materials. SEM micrographs revealed a highly irregular surface morphology characterized by a hierarchical pore structure. Both macro- and mesopores were observed to form simultaneously on the carbon surface, with pore sizes ranging from several tens of nanometers to the micrometer scale. Under elevated carbonization temperatures, KOH facilitates pore generation and enlargement through multiple chemical interactions, thereby substantially improving the overall porosity of the resulting carbon material:

$$6KOH + 2C \rightarrow 2K + 3H_2 + 2K_2CO_3$$

$$K_2CO_3 + 2C \rightarrow 2K + 3CO$$

As a result of this process, the generated metallic cations (K^+) diffuse into the carbon matrix, facilitating the formation of deep pore channels. Activation with KOH significantly enhances the surface structure of the carbon material. While mesopores promote the initial diffusion of adsorbate molecules toward the surface, micropores contribute to their effective retention within the pore network. Consequently, KOH-activated samples exhibit high adsorption capacity and favorable regeneration performance. Such materials are considered promising for applications in catalytic processes, gas storage systems, and as stationary phases in chromatographic separations. The SEM image representing the surface morphology of the KOH-activated carbon sample is presented in Figure 2.

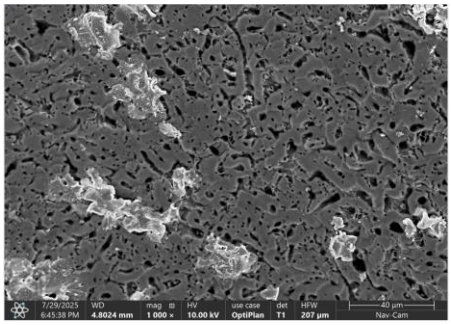


Figure 2. SEM image of activated carbon prepared using KOH activation.

Activated Carbon Prepared by $ZnCl_2$ Activation. During activation with $ZnCl_2$, the thermochemical decomposition of cellulose and hemicellulose is accelerated, leading to the formation of a more developed porous carbon framework. SEM images indicate the formation of a uniformly distributed mesoporous structure across the surface. The pore sizes are typically in the range of approximately 20–80 nm, which contributes to enhanced adsorption efficiency. $ZnCl_2$ acts as a dehydrating agent for organic components during the activation process. In this context, Zn^{2+} ions play a catalytic role within the carbon matrix, facilitating the stabilization of the surface morphology. Although $ZnCl_2$ is removed from the sample during the washing stage, the porous structure formed under its influence is retained. As a result, $ZnCl_2$-activated carbon samples exhibit a uniformly distributed mesoporous structure, which enhances their effectiveness as adsorbents. Such a structural configuration is particularly advantageous for the selective adsorption of heavy metal ions and organic dye molecules. The SEM image illustrating the surface morphology of the $ZnCl_2$-activated carbon sample is presented in Figure 3.

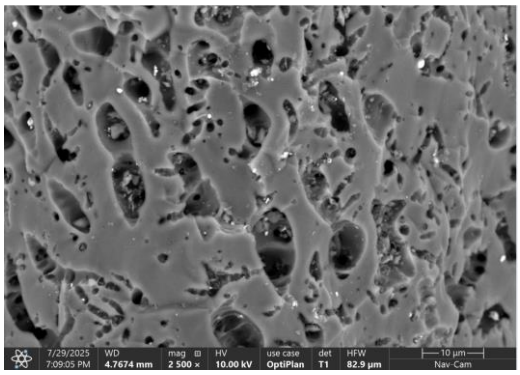


Figure 3. SEM image of activated carbon prepared using $ZnCl_2$ activation.

The types of activating agents used in the preparation of the obtained samples, along with their solution concentrations, impregnation ratios, temperature, and activation time parameters, are presented in Table 1. As shown in the table, each activating agent exhibits maximum efficiency under specific conditions. Activation with H_3PO_4 was carried out at a relatively lower temperature (650 °C) over a longer duration, which facilitated the formation of a predominantly microporous structure. In contrast, KOH activation required a higher temperature (800 °C), resulting in the development of expanded macro- and mesoporous networks. Meanwhile, $ZnCl_2$ activation conducted at an intermediate temperature (700 °C) and moderate duration promoted the formation of a nanoporous structure. Thus, the activation parameters significantly influence the degree of porosity and morphological characteristics of the resulting carbon materials.

The types of activating agents used in the preparation of the activated carbon samples, the solution concentrations, the sample-to-activator impregnation ratios, as well as the activation temperature and duration are presented in Table 1.

Table 1

Activation conditions applied in the preparation of activated carbon samples

Activating agent	Solution concentration	Sample-to-activator ratio	Activation temperature (°C)
H_3PO_4	50%	1:2	650
KOH	30%	1:2	800
$ZnCl_2$	40%	1:1	700

Conclusion. The results of the conducted study indicate that the surface morphology of carbon sorbents derived from walnut shells is directly influenced by the type of chemical activating agent employed. Activation with H_3PO_4 led to the formation of a uniformly distributed microporous structure, which enhances the stability of the adsorbent. In contrast, KOH activation under elevated temperature conditions promoted the development of macro- and mesopores. Meanwhile, samples activated using $ZnCl_2$ were characterized by a uniformly distributed mesoporous surface structure. Overall, the selection of the activating agent was found to be a key factor determining the porosity, adsorption performance, and structural stability of the carbon materials. The prepared sorbents demonstrate promising potential for application as stationary phases in chromatographic separation processes.

References

1. Le Van. Activated carbon derived from rice husk by NaOH activation and its application in supercapacitor //Progress in Natural Science: Materials International. – 2014. – T. 24. – №. 3. – C. 191-198.
2. Elangovan R., Philip L., Chandraraj K. Biosorption of chromium species by aquatic weeds: kinetics and mechanism studies //Journal of Hazardous materials. – 2008. – T. 152. – №. 1. – C. 100-112.
3. Shaarani F. W., Hameed B. H. Ammonia-modified activated carbon for the adsorption of 2, 4-dichlorophenol //Chemical engineering journal. – 2011. – T. 169. – №. 1-3. – C. 180-185.
4. Tian Y. et al. SF6 abatement in a packed bed plasma reactor: Role of zirconia size and optimization using RSM //Journal of Industrial and Engineering Chemistry. – 2021. – T. 94. – C. 205-216.
5. Sugiyama H., Hattori Y. Selective and enhanced CO2 adsorption on fluorinated activated carbon fibers //Chemical Physics Letters. – 2020. – T. 758. – C. 137909.
6. Koh K. H. et al. Elaborating nitrogen and oxygen dopants configurations within graphene electrocatalysts for two-electron oxygen reduction //ACS Materials Letters. – 2022. – T. 4. – №. 2. – C. 320-328.
7. Chu L. et al. Effect of carbonaceous materials on phosphorus removal in flow-through packed column systems //Environmental Science and Pollution Research. – 2024. – T. 31. – №. 50. – C. 60555-60567.
8. Uzokov J. R., Mukhamadiev N. K. Sorption characteristics of the mesoporous sorbents based on tetraethoxysilane and titanium oxide //European journal of molecular and clinical medicine. – 2020. – T. 7. – №. 7. – C. 656-660.
9. Ulugboyeva G. O. et al. Amorphous silica gel as a surfactant for saponins: support, synthesis, and texture characteristics //Central Asian Journal of Medical and Natural Science. – 2023. – T. 4. – №. 2. – C. 601-607.
10. Mamaziyaeva S. et al. Synthesis and their texture characteristics of mesoporous silica gel as surfactant supporting rutin //Central Asian Journal of Medical and Natural Science. – 2023. – T. 4. – №. 2. – C. 608-614.
11. Uzokov J. R., Muhamadiyev N. K. Synthesis of nanosorbents for chromatography from tetraethoxysilane and metal oxides //Proceedings of the International scientific-practical conference" Achievements, problems and prospects of complex innovative development of the Zarafshan oasis. – 2019. – C. 366-368.
12. Uzokov J. et al. Synthesis of SiO2· xZrO2 nanoporous sorbents and their texture and sorption characteristics //Science and innovation. – 2023. – T. 2. – №. A6. – C. 43-57.
13. Shrestha R. M. et al. Design of surface functionalization of waste material originated charcoals by an optimized chemical carbonization for the purpose of heavy metal removal from industrial waste waters //Microchemical Journal. – 2013. – T. 108. – C. 224-232.
14. Mavioglu Ayan E. et al. Oreganum stalks as a new biosorbent to remove textile dyes from aqueous solutions //CLEAN–Soil, Air, Water. – 2012. – T. 40. – №. 8. – C. 856-863.
15. Usman M. et al. Characterization and utilization of aqueous products from hydrothermal conversion of biomass for bio-oil and hydro-char production: a review //Green chemistry. – 2019. – T. 21. – №. 7. – C. 1553-1572.
16. Ergasheva D.R., Mukhamadiyev A.N., Mukhamadiyev N.Q., Uzokov J. Separation of organic dyes from solutions using modified activated carbon // Samarkand State University Scientific Bulletin. – 2025. – Issue 3 (151/2). – Vol. 3, No. 174. – P. 5–10.

SAMARQAND DAVLAT UNIVERSITETI ILMIY AXBOROTNOMASI

НАУЧНЫЙ ВЕСТНИК SCIENTIFIC REPORTS

Texnik muharrir **Sh.Xoliqulov**

Muharrirlar:

I.Sulaymonov - fil.f.d., dotsent
E.Arziqulov - f.-m.f.d., dotsent
O.Yusupova - fil.f.n., dotsent

Mas'ul muharrir:

A. Sh. Yarmuxamedov - f.-m.f.n.

Muassis: Samarqand davlat universiteti Manzil: 140104,
Samarqand shahri, Universitet xiyoboni, 15.
Telefon: (0 366) 240-38-47, Faks: (0 366) 239-13-87 e-mail:
axborotnoma.uz
SamDU «Ilmiy axborotnoma» jurnali tahririyati kompyuterida terildi. Bosishga 30.03.2026-yilda ruxsat etildi. Qog'oz o'lchami A-4. Nashriyot hisob tabog'i 10,00
Buyurtma raqami 833. Adadi 30 nusxa.

ISSN 2181-1296