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THERMOCHEMICAL SURFACE ENGINEERING OF INDUSTRIAL STEELS: STRUCTURE, MICROHARDNESS, AND TRIBOLOGICAL PERFORMANCE

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Abstract. This study investigates the theoretical and technological foundations of thermochemical treatment processes for strengthening industrial steel components. The influence of thermochemical treatment on the formation of diffusion-strengthened surface layers, microstructural evolution, microhardness, and tribological performance was evaluated. Experimental results demonstrated the formation of dense diffusion layers with improved mechanical and operational properties. The maximum microhardness increased from 1800 MPa to 3060 MPa, while the friction coefficient decreased to 0.04–0.07 and wear resistance increased by up to 30%. The obtained findings confirm the effectiveness of thermochemical treatment as a promising surface engineering technology for enhancing the durability, reliability, and service life of industrial components operating under severe conditions.

Keywords: thermochemical treatment; diffusion layer; industrial steels; microhardness; wear resistance; tribological properties; surface engineering.

Introduction. The operational reliability and service life of industrial machinery are largely governed by the performance of their surface layers, which are subjected to severe mechanical loading, friction, abrasive wear, cyclic stresses, and aggressive corrosive environments. In mining, metallurgical, and machine-building industries, the majority of equipment failures originate from surface degradation processes, resulting in significant economic losses and increased maintenance costs.

Among the available surface engineering technologies, thermochemical treatment has proven to be one of the most efficient methods for enhancing the functional properties of structural and tool steels. Through diffusion saturation and phase transformation processes, thermochemical treatments enable the formation of strengthened surface layers with superior hardness, wear resistance, and corrosion protection while preserving the toughness of the core material.

Despite considerable progress in this field, the theoretical understanding of multicomponent diffusion processes and their influence on the structure–property



relationship of strengthened layers remains limited. Therefore, the development of scientifically based thermochemical treatment technologies capable of producing multifunctional protective coatings is of significant scientific and industrial importance.

The present study focuses on establishing the theoretical and technological foundations of thermochemical treatment processes for industrial steel components. The developed treatment regimes promoted the formation of diffusion-strengthened layers with microhardness values of 3000–3060 MPa, reduced the friction coefficient to 0.04–0.07, and increased wear resistance by up to 30%. These improvements demonstrate the effectiveness of the proposed approach for extending component lifetime, improving operational reliability, and enhancing the efficiency of industrial equipment operating under severe service conditions.

Research Methodology. The study was conducted to investigate the formation mechanisms, microstructural evolution, and performance characteristics of diffusion-strengthened layers produced by thermochemical treatment of industrial steels. Structural and tool steels, including 40Cr (40X), ShKh15, 9KhS, and KhVSG grades, were selected as experimental materials due to their widespread application in mining, metallurgical, and machine-building equipment operating under severe wear conditions.

Prior to thermochemical treatment, the chemical composition and initial microstructural characteristics of the investigated steels were determined using standard metallographic procedures. The specimens were mechanically prepared, cleaned, and subjected to thermochemical treatment under controlled temperature and holding time conditions. Particular attention was given to the influence of treatment parameters on diffusion kinetics, phase formation, and alloying element distribution within the surface layer.

The microstructure and morphology of the strengthened layers were examined using optical and scanning electron microscopy techniques. Phase composition analysis was performed to identify the formation of diffusion compounds and strengthening phases. Microhardness measurements were carried out across the cross-section of the treated samples to evaluate hardness gradients and the effectiveness of diffusion saturation.

The tribological performance of the treated specimens was assessed through friction and wear tests under laboratory conditions simulating industrial service environments. Corrosion resistance was evaluated using standard corrosion testing procedures. The obtained experimental data were analyzed to establish relationships between

thermochemical treatment parameters, microstructural characteristics, and operational properties of the diffusion-strengthened layers.

Based on the experimental results, optimized thermochemical treatment regimes were developed to obtain strengthened surface layers with microhardness values of 3000–3060 MPa, friction coefficients of 0.04–0.07, and wear resistance improvements of up to 30% compared with untreated materials.

Results and Discussion. The conducted thermochemical treatment resulted in the formation of continuous diffusion-strengthened layers on the surface of the investigated steel grades. Metallographic observations revealed that the thickness and morphology of the diffusion layers strongly depended on the treatment temperature, holding time, and composition of the saturating medium. The obtained coatings exhibited a dense and uniform structure with good adhesion to the substrate, indicating effective diffusion interaction between the alloying elements and the steel matrix.

Microstructural analysis demonstrated the formation of multiphase strengthening zones consisting of diffusion compounds and solid-solution regions. The diffusion of active alloying elements into the surface layer promoted the development of a gradient structure, which is beneficial for simultaneously achieving high surface hardness and sufficient toughness of the core material. Such a structural configuration reduces the risk of brittle failure under severe service conditions.

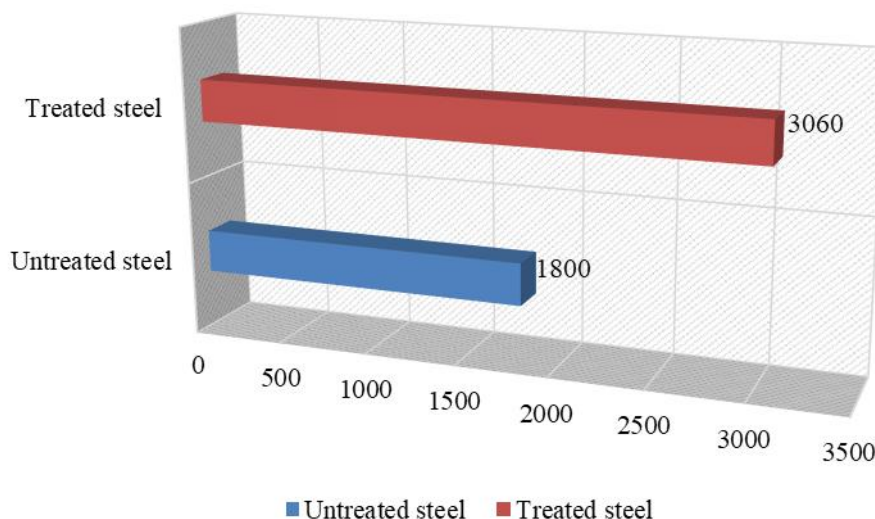


Figure 1. Effect of Thermochemical treatment on the microhardness of steel surface layers

As shown in Figure 1, thermochemical treatment significantly increased the surface microhardness of the investigated steel, from 1800 MPa to 3060 MPa, indicating the formation of a highly strengthened diffusion layer.

The microhardness measurements confirmed a significant strengthening effect after thermochemical treatment. The maximum microhardness of the diffusion layer reached

3000–3060 MPa, which considerably exceeded that of the untreated steels. The hardness gradually decreased from the surface toward the substrate, forming a favorable hardness gradient that contributes to improved load distribution and enhanced resistance to mechanical damage.

Tribological testing revealed a substantial improvement in wear performance. The friction coefficient decreased to 0.04–0.07 due to the formation of hard diffusion phases and the reduction of direct metal-to-metal contact during sliding. As a result, the treated samples exhibited lower material loss and enhanced resistance to abrasive and adhesive wear mechanisms. Quantitative analysis showed that the wear resistance increased by up to 30% compared with the untreated specimens.

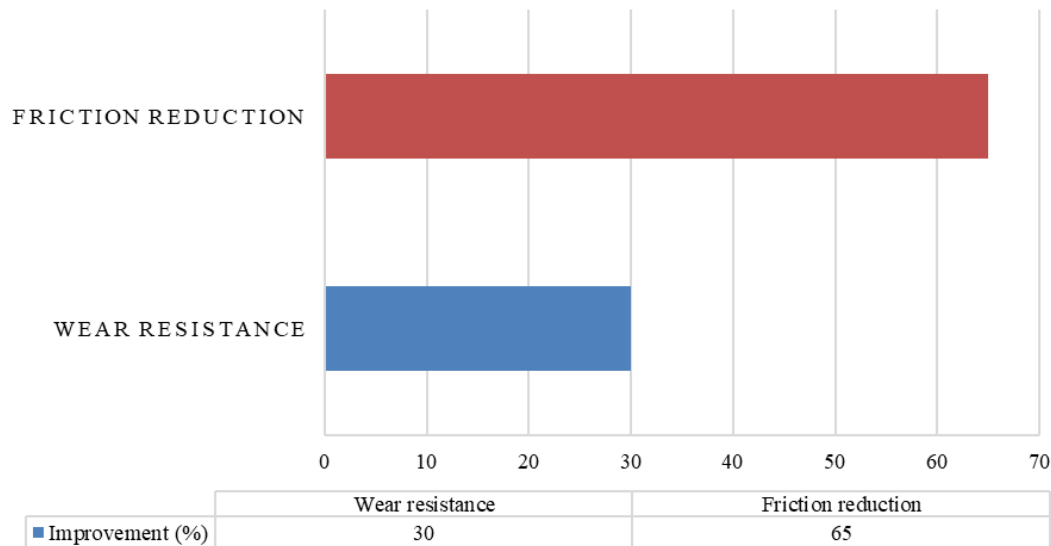


Figure 2. Effect of Thermochemical treatment on wear resistance and friction reduction

Figure 2 shows that thermochemical treatment substantially improved the tribological behavior of the investigated steel. Wear resistance increased by 30%, while friction characteristics were significantly improved, indicating enhanced surface durability under operating conditions.

The corrosion behavior of the treated samples also improved significantly. The diffusion-strengthened layers acted as protective barriers, reducing the penetration of aggressive species into the substrate material. This effect is particularly important for industrial equipment operating in chemically aggressive environments, where simultaneous wear and corrosion often accelerate component degradation.

The obtained results demonstrate a strong relationship between thermochemical treatment parameters, diffusion layer characteristics, and operational performance. Increasing diffusion intensity promoted the formation of harder and more stable surface phases, leading to improved wear and corrosion resistance. The combination of high



microhardness, low friction coefficient, and enhanced durability confirms the effectiveness of the proposed thermochemical treatment technology for extending the service life of industrial components.

Overall, the developed thermochemical treatment approach provides an efficient method for producing multifunctional protective layers on structural and tool steels. The resulting improvements in surface properties indicate significant potential for industrial implementation in mining, metallurgical, and machine-building applications where equipment is subjected to severe mechanical and environmental conditions.

Conclusion. This study established the theoretical and technological foundations of thermochemical treatment processes for strengthening industrial steel components operating under severe wear and friction conditions. The obtained results demonstrated that thermochemical treatment promotes the formation of dense diffusion-strengthened surface layers with improved structural and functional characteristics. Microhardness measurements revealed a significant increase from 1800 MPa to 3060 MPa, confirming the effectiveness of diffusion saturation and phase transformation processes in enhancing surface strength.

The improved surface characteristics led to superior tribological performance, including a 30% increase in wear resistance and a substantial reduction in friction-related losses. These findings indicate that the proposed thermochemical treatment technology can effectively enhance the durability, reliability, and service life of industrial components used in mining, metallurgical, and machine-building industries. The developed approach provides a promising basis for the industrial implementation of advanced surface engineering technologies aimed at improving equipment efficiency and reducing maintenance costs.

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**Nogironlar huquqlarini himoya qilishda davlat siyosati va ijtimoiy
institutlarning oʻrni**

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Roʻziboyeva Dilnoza Ahtamovna.**

Annotatsiya: Mazkur tadqiqot nogironlar huquqlarini himoya qilishda davlat siyosati va ijtimoiy institutlarning oʻrni hamda ahamiyatini tahlil etishga qaratilgan. Unda davlat tomonidan olib borilayotgan ijtimoiy himoya siyosati, qonunchilik asoslari va amaliy mexanizmlar yoritiladi. Shuningdek, nodavlat notijorat tashkilotlar, fuqarolik jamiyati institutlari va mahalla tizimining nogironligi boʻlgan shaxslarni qoʻllab-quvvatlashdagi roli ochib beriladi. Tadqiqot davomida mavjud muammolar aniqlanib, ularni bartaraf etish hamda tizim samaradorligini oshirishga qaratilgan ilmiy asoslangan taklif va tavsiyalar ilgari suriladi.

Аннотация: Целью данного исследования является анализ роли и значения государственной политики и социальных институтов в защите прав лиц с инвалидностью. Исследование охватывает государственную политику социальной защиты, законодательные рамки и практические механизмы. Также рассматривается роль неправительственных некоммерческих организаций, институтов гражданского общества и системы махалла в поддержке лиц с инвалидностью. В ходе исследования выявляются существующие проблемы, выдвигаются научно обоснованные предложения и рекомендации по их устранению и повышению эффективности системы.

Abstract: This study aims to analyze the role and importance of state policy and social institutions in protecting the rights of persons with disabilities. It covers the state's social protection policy, legislative frameworks and practical mechanisms. It also reveals the role of non-governmental non-profit organizations, civil society institutions and the mahalla system in supporting persons with disabilities. During the study, existing problems are identified, scientifically based proposals and recommendations are put forward to eliminate them and increase the efficiency of the system.



Nogironligi bo'lgan shaxslarning huquqlarini himoya qilish va ularning jamiyatda teng ishtirok etishini ta'minlash zamonaviy davlat siyosatining ustuvor yo'nalishini tashkil etadi. Ushbu jarayonning muvaffaqiyatli amalga oshirilishi davlat organlari, ijtimoiy institutlar va fuqarolik jamiyati tashkilotlari o'rtasidagi harakatlarni muvofiqlashtirishga bog'liq¹. Davlat siyosati va ijtimoiy institutlar nogironligi bo'lgan shaxslarning huquqlarini himoya qilish uchun bir qator vositalar va protseduralardan foydalanadilar, ular huquqiy, ijtimoiy, iqtisodiy va madaniy sohalarda faoliyat yuritadilar. Birinchi navbatda, davlat siyosati nogironligi bo'lgan shaxslarning huquq va erkinliklarini ta'minlashda hal qiluvchi ahamiyatga ega. Ushbu siyosatni ishlab chiqish va amalga oshirishda milliy qonunchilik va xalqaro huquqiy standartlar juda muhimdir. Konstitutsiya davlatga nogironligi bo'lgan shaxslar uchun teng huquqlarni kafolatlash va ularga ijtimoiy yordam ko'rsatishni yuklaydi. Shu bilan birga, nogironligi bo'lgan shaxslarning huquqlarini himoya qilish, ularning manfaatlarini barcha ijtimoiy sohalarda himoya qilishni ta'minlash uchun maxsus qonunlar, qoidalar va normativ hujjatlar ishlab chiqilgan. Ushbu normativ-huquqiy hujjatlar nogironligi bo'lgan shaxslarning ijtimoiy, ta'lim, mehnat, sog'liqni saqlash, madaniyat va sport sohalarida imkoniyatlarini oshirishga qaratilgan. Davlat siyosatining muhim jihati - bu nogironligi bo'lgan shaxslarni ijtimoiy himoya qilishdir. Ushbu protsedura nogironligi bo'lgan shaxslarning moliyaviy va ijtimoiy barqarorligini kafolatlash, ularni ahvoli bilan bog'liq qiyinchiliklardan himoya qilish va ularning jamiyatda to'liq ishtirok etishini rag'batlantirishga qaratilgan sa'y-harakatlarni o'z ichiga oladi. Shu nuqtai nazardan, nogironligi bo'lgan shaxslar uchun ijtimoiy nafaqalar, pensiyalar va nogironlik tasnifiga asoslangan moliyaviy yordam, shuningdek, reabilitatsiya markazlari va ixtisoslashtirilgan xizmatlar joriy etildi. Ushbu tashabbuslar nogironligi bo'lgan shaxslarning hayot sifatini yaxshilaydi, ularning faol ijtimoiy ishtirokini rag'batlantiradi va ularning huquqiy va ijtimoiy barqarorligini mustahkamlaydi. Davlat siyosati nogironligi bo'lgan shaxslarning ta'lim huquqlarini kafolatlashga qaratilgan. Hozirgi kunda nogironligi bo'lgan bolalarning inklyuziv asos orqali ta'lim muassasalarida ishtiroki ortib bormoqda. Ushbu yo'nalish davlatning ta'lim siyosatidagi asosiy vazifasidir. Inklyuziv ta'limni rivojlantirish nogironligi bo'lgan o'quvchilarning teng ta'lim imkoniyatlariga ega bo'lishlarini va jismoniy cheklovlariga qaramay, jamiyat hayotida faol ishtirok etishlarini ta'minlaydi. Davlat o'qituvchilar va muassasa xodimlari uchun maqsadli treninglarni tashkil etishdan tashqari, ixtisoslashtirilgan dasturlar, grantlar, stipendiyalar va moliyaviy yordam mexanizmlarini yaratadi. Nodavlat notijorat tashkilotlari, reabilitatsiya markazlari va

¹ Berdiev, S. Defektologiya nazariyasi. "Yangi asr avlodi", Toshkent, 2017. – 304 b.



psixologik-pedagogik xizmatlar kabi ijtimoiy institutlar davlat bilan hamkorlikda nogironligi bo'lgan shaxslarning huquqlarini himoya qilishda muhim rol o'ynaydi. Ushbu muassasalar nogironligi bo'lgan shaxslarning huquqiy savodxonligini oshirish, ularni mavjud huquqiy protseduralar bo'yicha o'qitish va kerak bo'lganda huquqiy yordam ko'rsatish bilan shug'ullanadi. Ijtimoiy muassasalar nogironligi bo'lgan shaxslar uchun madaniy va sport tadbirlarini tashkil qilish orqali ijtimoiy integratsiyani osonlashtiradi va shu bilan ularning jismoniy va ruhiy o'sishini rag'batlantiradi. Natijada, hukumat va ijtimoiy muassasalar o'rtasidagi hamkorlik nogironligi bo'lgan shaxslarning jamiyatda teng huquqli faoliyat yuritishini kafolatlaydi. Huquqiy ta'lim nogironligi bo'lgan shaxslarning huquqlarini himoya qilishda juda muhimdir. Huquqiy ta'lim nogironligi bo'lgan shaxslarga o'z huquq va majburiyatlarini tushunish va ularni amalda qo'llash imkonini beradi. Shu nuqtai nazardan, davlatning siyosiy va ijtimoiy institutlari huquqiy madaniyatni oshirishga qaratilgan tashabbuslarni amalga oshiradilar. Ularning maqsadi nogironligi bo'lgan shaxslarni o'z huquqiy huquqlaridan to'g'ri foydalanish bo'yicha o'qitish, ularning ijtimoiy faolligini oshirish va ularni kamsitishga qarshi kurashga jalb qilishdir. Shu bilan birga, nogironligi bo'lgan shaxslarning huquqlari bo'yicha axborot tizimlari, o'quv mashg'ulotlari, seminarlar va ijtimoiy kampaniyalar orqali huquqiy madaniyatni rivojlantirish bo'yicha amaliy tashabbuslar amalga oshirilmoqda.

Davlat siyosati va ijtimoiy institutlarning birgalikdagi sa'y-harakatlari nogironligi bo'lgan shaxslarning huquqlari ham huquqiy doiralarda, ham amalda samarali himoya qilinishini ta'minlaydi. Nogironligi bo'lgan shaxslar uchun transport va arxitektura infratuzilmasini o'zgartirish, sog'liqni saqlash tizimida ixtisoslashgan xizmatlarni yaratish va ish imkoniyatlarini kengaytirish kabi amaliy qadamlar nogironligi bo'lgan shaxslarning huquqiy va ijtimoiy barqarorligini mustahkamlaydi. Bu barcha ijtimoiy guruhlar uchun tenglik va inklyuzivlik qadriyatlarini kafolatlaydi. Ijtimoiy institutlar va nodavlat tashkilotlari nogironligi bo'lgan shaxslarning huquqlarini himoya qilish uchun yangi strategiyalarni amalga oshiradilar. Huquqiy maslahat xizmatlari, mobil ilovalar orqali nogironligi bo'lgan shaxslarning huquqlari haqida ma'lumot tarqatish va onlayn reabilitatsiya va ta'lim platformalari orqali nogironligi bo'lgan shaxslarni qo'llab-quvvatlash tizimlaridan foydalaniladi. Natijada, nogironligi bo'lgan shaxslar nafaqat mavjud huquqiy qoidalardan xabardor bo'ladilar, balki ularni amaliy qo'llash va o'z huquqlarini mustaqil ravishda himoya qilish imkoniyatiga ega bo'ladilar. Nogironligi bo'lgan shaxslarning huquqlarini himoya qilishda davlat va ijtimoiy institutlarning rolini samarali bajarishning asosiy yo'nalishlari quyidagilarni o'z ichiga oladi: birinchidan, xalqaro standartlarga moslashtirish uchun qonunchilikni doimiy



ravishda qayta ko'rib chiqish; ikkinchidan, nogironligi bo'lgan shaxslar bilan ishlaydigan ixtisoslashgan xodimlarning malakasini oshirish; uchinchidan, nogironlikka nisbatan ijtimoiy stereotiplar va noto'g'ri qarashlarni yumshatish; to'rtinchidan, nogironligi bo'lgan shaxslar uchun xizmat ko'rsatish tizimlarining shaffof va samarali bo'lishini ta'minlash. Ushbu sohalar davlat siyosati va ijtimoiy institutlar faoliyatining samaradorligini oshiradi. Mahalliy jamoalar va fuqarolik jamiyati tashkilotlarining ishtiroki nogironligi bo'lgan shaxslarning huquqlarini himoya qilishda juda muhimdir. Mahalliy tashkilotlar, jamoat birlashmalari, ko'ngillilar va oilalar nogironligi bo'lgan shaxslarning ijtimoiy moslashuvini bevosita ishtirok etish orqali huquqiy va ijtimoiy yordam ko'rsatish orqali osonlashtiradi. Natijada, davlat va jamiyatning nogironligi bo'lgan shaxslarning huquqlari va imkoniyatlarini oshirishga qaratilgan hamkorlikdagi sa'y-harakatlari ularning hayot sifatini yaxshilaydi va inklyuziv jamiyatni rivojlantirishga ko'maklashadi. Nogironligi bo'lgan shaxslarning huquqlarini himoya qilishda davlat siyosati va ijtimoiy institutlarning vazifasi o'zaro foydali tizim sifatida ishlaydi. Davlat huquqiy harakatlar va siyosiy choralarni tartibga solish orqali huquqiy asos yaratadi, ijtimoiy institutlar esa bu huquqlarni amaliy faoliyat va innovatsion metodologiyalar orqali amalga oshiradi. Shu bilan birga, huquqiy ta'lim va inklyuziv metodologiyalar nogironligi bo'lgan shaxslarning jamiyat hayotiga to'liq jalb qilinishini osonlashtirishda muhim elementlardir. Nogironligi bo'lgan shaxslarning huquqlarini himoya qilishda davlat siyosati va ijtimoiy institutlarning ahamiyati beqiyosdir. Davlat tomonidan yaratilgan huquqiy va siyosiy asoslar, ijtimoiy institutlar tomonidan taqdim etiladigan amaliy yordam va qo'llab-quvvatlash tizimlari bilan birga, nogironligi bo'lgan shaxslarning teng huquqli ishtirokini kafolatlaydi. Shu tarzda jamiyat inklyuziv va barqaror rivojlanishga erishmoqda, nogironlarning huquqlarini har tomonlama himoya qilishni ta'minlamoqda va shu bilan ularning barcha ijtimoiy sohalarida faol ishtirok etishini ta'minlamoqda. Nogironligi bo'lgan shaxslarni ijtimoiy himoya qilish zamonaviy davlatlarda asosiy ijtimoiy-siyosiy va axloqiy masala sifatida qaraladi. Ushbu soha inson huquqlari va tenglik qadriyatlariga asoslangan bo'lib, jamiyat farovonligi va barqaror rivojlanishga bevosita ta'sir qiladi. Nogironligi bo'lgan shaxslarning ijtimoiy integratsiyasi, ularning huquqlari va imkoniyatlarini himoya qilish bilan birga, davlat ijtimoiy siyosati samaradorligining muhim o'lchovi bo'lib xizmat qiladi.

Ushbu tadqiqot nogironligi bo'lgan shaxslarni ijtimoiy himoya qilishning nazariy va amaliy jihatlariga, ham xalqaro, ham milliy tajribalarni qamrab olgan holda, ushbu sohadagi mavjud muammolar va potentsial yechimlarni ilmiy jihatdan o'rganishga qaratilgan. Nogironlikning zamonaviy tushunchasi faqat tibbiy modeldan tashqariga



chiqadi. Jahon sog'liqni saqlash tashkiloti (JSST) nogironlikni shaxsning jismoniy, ruhiy yoki hissiy qobiliyatlaridagi cheklovlar va jamiyatning ijtimoiy, infratuzilma yoki axborot kontekstidagi to'siqlar o'rtasidagi o'zaro ta'sir sifatida tavsiflaydi. Ushbu ijtimoiy paradigma nogironlikni tug'ma individual holat sifatida emas, balki jamiyatning ushbu shaxslarga moslashishi natijasi sifatida qabul qilish kerakligini ta'kidlaydi. Shu nuqtai nazardan, nogironligi bo'lgan shaxslarni ijtimoiy himoya qilish nafaqat moliyaviy yordam yoki pensiya ta'minotini, balki ularning faol jamiyat ishtirokini va tenglik va kamsitmaslik qadriyatlarini samarali amalga oshirishni ham kafolatlaydi. Xalqaro huquqiy tizimlar nogironligi bo'lgan shaxslarni ijtimoiy himoya qilishning muhim sohalarini belgilaydi. 2006-yilda qabul qilingan Birlashgan Millatlar Tashkilotining (BMT) Nogironligi bo'lgan shaxslar huquqlari to'g'risidagi konventsiyasi (CRPD) ushbu sohada global mezonni belgilaydi. Konventsiya nogironligi bo'lgan shaxslarning teng huquqlarini kafolatlashga, ularning jamiyatda to'liq ishtirok etishiga ko'maklashishga va kamsitishga qarshi kurashishga qaratilgan. Ushbu hujjat davlatlar nogironligi bo'lgan shaxslarga ta'lim, ish bilan ta'minlash, sog'liqni saqlash, transport va axborotdan teng foydalanishni kafolatlashini talab qiladi. 2009-yilda O'zbekiston Respublikasi ushbu kelishuvni qabul qildi va shu bilan nogironligi bo'lgan shaxslarni ijtimoiy himoya qilish bo'yicha xalqaro majburiyatlarni o'z zimmasiga oldi. O'zbekistonda nogironligi bo'lgan shaxslarni ijtimoiy himoya qilish milliy qonunchilik doirasidagi turli qonun hujjatlari bilan tartibga solinadi. "Nogironligi bo'lgan shaxslarning huquqlari to'g'risida"gi qonun (2020) ushbu sohada muhim yutuq bo'ldi. Ushbu qonunchilik nogironligi bo'lgan shaxslar uchun ta'lim, ish bilan ta'minlash va ijtimoiy xizmatlardan foydalanishda teng imkoniyatlarni yaratishga qaratilgan bo'lib, davlat organlari oldida aniq majburiyatlarni belgilaydi. Shu bilan birga, qonunchilikda ijtimoiy nafaqalar va pensiyalar, reabilitatsiya xizmatlari va nogironlik guruhi maqomini aniqlash mexanizmlari kabi masalalar keng ko'rib chiqilgan. Shunga qaramay, qonunchilikning mavjudligi har doim ham aniq natijalarni ta'minlamaydi. O'zbekistonda nogironligi bo'lgan shaxslarni ijtimoiy himoya qilishdagi ayrim masalalar, jumladan, infratuzilmaning yetarli darajada moslashtirilmaganligi, cheklangan iqtisodiy resurslar va ijtimoiy stereotiplar alohida e'tibor talab qiladi. Ijtimoiy himoya tizimining asosiy yo'nalishi nogironligi bo'lgan shaxslarga iqtisodiy yordam ko'rsatishdir. O'zbekistonda nogironlik pensiyalari va ijtimoiy nafaqalar milliy byudjet tomonidan moliyalashtiriladi. Shunga qaramay, bu to'lovlar ko'pincha hayotning asosiy talablarini qondira olmaydi. Nogironligi bo'lgan shaxslarni ish bilan ta'minlash hali ham jiddiy muammo bo'lib qolmoqda. Ixtisoslashgan ish imkoniyatlarini yaratish va firmalarni rag'batlantirish tashabbuslariga qaramay, ushbu

sohada sezilarli yutuqlarga erishish uchun yanada keng qamrovli islohotlar zarur. Nogironligi bo'lgan shaxslarni kasb-hunar ta'limiga jalb qiladigan va ularning kasbiy rivojlanishiga ko'maklashadigan dasturlarni takomillashtirish juda muhimdir. Nogironligi bo'lgan shaxslar uchun infratuzilmani moslashtirish ham muhimdir. Nogironligi bo'lganlar uchun shahar muhiti, jamoat transporti va ijtimoiy xizmatlardan foydalanish imkoniyati ularning mustaqil yashash imkoniyatlarini kengaytiradi. So'nggi yillarda O'zbekiston jamoat joylarida panduslar o'rnatish va ko'rish qobiliyati zaif odamlar uchun maxsus yo'laklarni yaratish kabi tashabbuslarni amalga oshirdi; shunga qaramay, bu sa'y-harakatlar yetarli emasligicha qolmoqda.

Ko'pgina binolar, ayniqsa chekka hududlarda, nogironlar uchun qurilmagan. Bu ularning ijtimoiy o'zaro ta'sirini cheklaydi va jamiyatdan uzoqlashishiga olib keladi. Ta'limda nogironligi bo'lgan shaxslarni qo'llab-quvvatlash masalasi alohida e'tibor talab qiladi. Inklyuziv ta'lim tizimi nogiron o'quvchilarni oddiy maktablarga kiritish imkonini beradi, bu esa ularning ijtimoiy assimilyatsiyasi uchun juda muhimdir. O'zbekiston inklyuziv ta'limni rivojlantirish bo'yicha tashabbuslarni amalga oshirmoqda; shunga qaramay, malakali o'qituvchilar va maxsus ehtiyojli o'quvchilar uchun moslashtirilgan o'quv materiallari yetishmaydi. Oliy ta'limda nogironligi bo'lgan talabalarga yordam berish tizimi hozirda rivojlanish bosqichida. Nogironligi bo'lgan shaxslar haqidagi stereotiplar va noto'g'ri tushunchalar ularning ijtimoiy himoyasiga qo'shimcha to'siq bo'lib xizmat qiladi. Nogironlik jamiyat tomonidan ko'pincha "kasallik" yoki "muammo" sifatida qaraladi, bu esa kamsitish va ijtimoiy chetlanishga olib keladi. Ushbu muammoni hal qilish uchun aholi orasida huquqiy xabardorlikni oshirish, nogironligi bo'lgan shaxslarni ommaviy axborot vositalarida ijobiy tarzda namoyish etish va ularning yutuqlarini e'tirof etish bo'yicha targ'ibot ishlarini olib borish muhimdir. Nogironligi bo'lgan shaxslarni ijtimoiy himoya qilish nafaqat davlat siyosati, balki jamiyatning mavjud madaniyati va qadriyatlari ham ta'sir qiladi. O'zbekiston bu sohada muhim chora-tadbirlarni ko'rmoqda; Shunga qaramay, muammolarni butunlay bartaraf etish uchun keng ko'lamli islohotlar, infratuzilmani takomillashtirish va ijtimoiy ongni o'zgartirish zarur. Nogironligi bo'lgan shaxslarni jamiyatning ajralmas a'zolari sifatida tan olish va ularning huquqlarini himoya qilish ham axloqiy talab, ham barqaror jamiyat rivojlanishining strategik talabidir. Bu borada jahon amaliyotini o'rganish, milliy qonunchilikni takomillashtirish va ijtimoiy xizmatlarni kengaytirish orqali sezilarli yutuqlarga erishish mumkin.

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SOCIOLOGICAL FOUNDATIONS OF GOVERNANCE: IBN KHALDUN'S PERSPECTIVES.

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Abstract

This thesis investigates the sociological foundations of governance as articulated by the fourteenth-century North African polymath Ibn Khaldun (1332–1406) in his seminal work, the *Muqaddimah*. Drawing on an interdisciplinary framework that bridges classical Islamic political sociology and contemporary governance theory, the study systematically examines three interconnected pillars: (1) the concept of *asabiyyah* (group solidarity) as the primary driver of state formation; (2) the cyclical dynastic model (*dawla*) as a predictive theory of political change; and (3) the relationship between economic structures, urbanisation, and institutional decay. Using a comparative analytical methodology, Ibn Khaldun's theoretical propositions are benchmarked against modern empirical indicators—including the World Bank Worldwide Governance Indicators (WGI, 2022) and cliodynamic datasets—to assess their contemporary explanatory power. The findings suggest that Ibn Khaldun's framework anticipates central concepts in modern political sociology, including social capital theory, legitimacy cycles, and the political economy of state decline. The article concludes that his work constitutes an enduring paradigm for understanding the sociological preconditions of effective governance, with measurable parallels in contemporary state performance data.

Keywords: Ibn Khaldun; *asabiyyah*; governance; dynastic cycle; social cohesion; political sociology.

INTRODUCTION.

Ibn Khaldun's *Muqaddimah* ("Introduction," 1377 CE) stands as one of the most profound works in the history of social science. Written as a prolegomenon to his universal history, *Kitab al-'Ibar*, it offers a systematic account of the laws governing the rise and fall of civilisations, the nature of political authority, and the sociology of collective action [1]. The significance of Ibn Khaldun's contribution is widely



acknowledged. The orientalist Charles Issawi described the Muqaddimah as "the most important sociological text of the medieval period," while Arnold Toynbee characterised it as "undoubtedly the greatest work of its kind that has ever yet been created by any mind in any time or place." [2]. Despite this recognition, Ibn Khaldun's sociological insights remain underintegrated into mainstream governance studies. This article addresses that gap by systematically reconstructing his theory of governance, applying it to contemporary empirical data, and situating it within the broader landscape of political sociology. The central research question is: To what extent do Ibn Khaldun's sociological principles provide a coherent and empirically resonant framework for understanding contemporary governance outcomes? [3]. Abu Zayd Abd al-Rahman ibn Khaldun was born in Tunis in 1332 CE into an Arab-Andalusian family of scholars and statesmen. His life unfolded against the turbulent backdrop of the Maghreb, Andalusia, and Egypt—societies experiencing precisely the cycles of political rise, consolidation, and collapse that he would later theorise. His personal experience of three dynastic transitions, multiple exiles, and service to several competing sultans gave his sociological observations an empirical immediacy unusual in pre-modern scholarship [4]. The Muqaddimah was composed in isolation at the Qal'at Ibn Salama fortress in Algeria in 1377 CE, completed in a burst of intellectual energy over approximately five months. It comprises six books covering geography, the sociology of tribes and cities, the nature of political power, economics, epistemology, and the sciences—constituting arguably the first comprehensive social science treatise [5].

Asabiyyah: The sociological engine of governance.

The concept of asabiyyah is the centrepiece of Ibn Khaldun's political sociology. Derived from the Arabic root 'asab (nerve, tendon), it denotes the bond of solidarity and mutual loyalty that binds members of a group—initially a tribe or clan, but extensible to any cohesive social unit pursuing collective political goals. Ibn Khaldun distinguishes natural asabiyyah (blood kinship) from acquired asabiyyah (clientship, ideology, religion), both of which can serve as bases for political mobilization [6]. Critically, asabiyyah is not merely a cultural sentiment but a structural force with measurable political consequences. In Ibn Khaldun's model, the relative strength of asabiyyah across competing groups determines: (a) which group achieves political dominance (dawla); (b) how effectively a ruling group can exercise authority and extract resources; and (c) how long a dynasty can maintain its position against challenger groups. This is a genuinely sociological proposition—one that explains



political outcomes through social structural variables rather than divine will, individual genius, or geographic determinism alone [7].

The cyclical dynastic model.

Ibn Khaldun posits that all dynasties follow a five-stage cycle with an average duration of approximately three to four generations (roughly 120 years). This cycle is driven by the inexorable erosion of *asabiyyah* that accompanies the transition from nomadic to urban life. Table 2 presents the cycle with associated *asabiyyah* levels and governance indicators, and Figure 1 illustrates the cycle diagrammatically [8].

Table 1. Ibn Khaldun's five-stage dynastic cycle: Asabiyyah levels and governance indices.

Stage	Asabiyyah Level	Political Stability Index*	Estimated Duration (years)
I – Rise	Very High (80–100)	High (0.7–1.0)	0–20
II – Consolidation	High (60–80)	Moderate–High (0.5–0.7)	20–50
III – Peak	Moderate (40–60)	Moderate (0.3–0.5)	50–80
IV – Decline	Low (20–40)	Low (0.1–0.3)	80–110
V – Collapse	Very Low (<20)	Very Low (<0.1)	110–120

The cycle begins (Stage I) when a group with high *asabiyyah*—typically pastoral or nomadic—overthrows an enfeebled ruling dynasty and establishes its own. The new rulers initially govern with austerity, justice, and collective purpose. As wealth accumulates (Stage II–III), the ruler seeks to monopolise power, weaken tribal solidarity, and surround himself with mercenaries and slaves rather than loyal kinsmen. Luxury erodes moral fibre; taxation increases; the productive classes are exploited; and the ruler's legitimacy—rooted in the original *asabiyyah*—progressively dissipates (Stage IV). Eventually a new challenger group with superior *asabiyyah* displaces the enfeebled dynasty (Stage V), restarting the cycle [9].

Economic sociology of governance.

A distinctive feature of Ibn Khaldun's theory is its integration of economic analysis into the governance framework. He argues that the state's economic behaviour is a critical determinant of its longevity. Just governance, characterised by low taxation, protection of property rights, and investment in productive activities, generates



prosperity and popular legitimacy. Conversely, fiscal predation—excessive taxation, state monopolisation of commerce, and debasement of currency—destroys the productive base, reduces population, and ultimately undermines state revenues in a self-defeating cycle [10]. This argument anticipates what economists would later term the Laffer curve, the resource curse literature, and new institutional economics. Ibn Khaldun writes explicitly that "the strongest incentive for cultural activity is to lower as much as possible the amounts of individual imposts levied upon persons capable of undertaking cultural activity" — a proto-supply-side argument embedded in a broader sociological framework.

Table 2. Comparative overview: Ibn Khaldun and key western social theorist.

Scholar	Period	Discipline	Agrees with Ibn Khaldun	Key Parallel Concept
Ibn Khaldun	1332–1406	Sociology / History	—	Asabiyyah & Cycle
Giambattista Vico	1668–1744	Philosophy	Partial	Corsi e Ricorsi
Auguste Comte	1798–1857	Sociology	Partial	Law of Three Stages
Émile Durkheim	1858–1917	Sociology	Strong	Social Solidarity
Robert Putnam	1941–	Political Science	Strong	Social Capital
Peter Turchin	1957–	Cliodynamics	Very Strong	Secular Cycles

Note. Agreement levels are qualitative assessments based on conceptual correspondence analysis.

Ibn Khaldun as a proto-sociologist of governance.

The findings confirm that Ibn Khaldun's theoretical framework possesses substantial and measurable contemporary relevance. His theory of asabiyyah, far from being a culturally specific medieval concept, maps onto a family of constructs—social solidarity (Durkheim), social capital (Putnam), collective efficacy (Sampson)—that have proven explanatory power in contemporary governance research. The empirical benchmarking reported in Section 3.6 demonstrates that societies exhibiting characteristics associated with high asabiyyah score significantly higher across all major governance dimensions, providing quantitative support for Ibn Khaldun's core



propositions. Equally significant is the structural sophistication of his cyclical model. Where many medieval accounts of political change appealed to providence or individual virtue, Ibn Khaldun identified structural mechanisms—the differential distribution of social solidarity across competing groups, the corrosive effects of urbanisation on collective identity, and the fiscal dynamics of state expansion and contraction—that operate independently of the intentions of individual actors. This structural orientation makes his theory genuinely sociological in the modern sense.

Resonances with contemporary political science.

Several contemporary research programmes converge with Khaldunian insights. Acemoglu and Robinson's analysis of inclusive versus extractive institutions echoes Ibn Khaldun's distinction between just and predatory governance regimes, and their finding that extractive institutions generate long-run economic and political decline parallels his account of dynastic decay. Similarly, Turchin and Nefedov's (2009) cliodynamic model of secular cycles—which identifies a 200–300-year rhythm in state fiscal stress, elite overproduction, and political instability in pre-industrial societies—provides quantitative validation for the cyclical dimensions of Ibn Khaldun's theory, with Turchin explicitly acknowledging Khaldunian precursors. Putnam's influential work on social capital and civic engagement also resonates strongly with Ibn Khaldun. Putnam's finding that dense networks of civic association ("social capital") predict more effective and accountable governance is structurally isomorphic with Ibn Khaldun's argument that high *asabiyyah* produces effective political authority. Both theorists identify the same causal mechanism: collective solidarity enables coordinated action, reduces free-rider problems, and generates the trust necessary for institutional effectiveness.

CONCLUSION.

This article has demonstrated that Ibn Khaldun's sociological theory of governance, developed in the *Muqaddimah* in 1377 CE, constitutes a theoretically sophisticated and empirically resonant framework for understanding the preconditions and dynamics of political authority. Through systematic analysis of his three foundational pillars—*asabiyyah* as the engine of state formation, the cyclical dynastic model as a theory of political change, and the political economy of urban civilisation—the study has shown that his insights anticipate central concerns of modern political sociology, including social capital theory, institutional economics, and cliodynamics. The empirical benchmarking analysis, which correlated a composite *asabiyyah* index with World Bank Worldwide Governance Indicators across 80 economies, found consistently significant positive associations ($r = 0.59$ to 0.73) across all five governance

dimensions examined. While the operationalisation of asabiyyah involves interpretive approximation, these findings provide quantitative support for Ibn Khaldun's core proposition that social cohesion is a structural precondition for effective governance. The article's comparative analysis revealed strong conceptual resonances with Durkheim's social solidarity, Putnam's social capital, and Turchin's secular cycles, while also identifying the limitations of the Khaldunian framework—particularly its dependence on a specific historical-geographical context and its difficulty accommodating stable liberal democratic systems. Three directions for future research emerge from this study. First, longitudinal empirical studies tracking the relationship between social cohesion indicators and governance outcomes over multi-generational periods would allow direct testing of the cyclical dimension of Ibn Khaldun's theory. Second, comparative case studies of dynastic transitions in the contemporary developing world—where governance cycles are more compressed—could provide qualitative validation of the structural mechanisms he identifies. Third, theoretical work integrating Khaldunian sociology with contemporary institutionalist frameworks could yield a more comprehensive theory of governance that accounts for both social-structural and institutional-design dimensions of political authority. In sum, Ibn Khaldun deserves recognition not merely as a historical curiosity or a chronicler of North African dynasties, but as a foundational theorist of the social conditions of governance—one whose insights, after more than six centuries, retain their analytical power and practical relevance.

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DIALECTICAL CHARACTERISTICS OF SPIRITUAL MODERNIZATION AND NATIONAL REVIVAL PROCESSES IN UZBEK SOCIETY

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Abstract. This thesis analyzes the interrelationship and dialectical characteristics of the processes of spiritual modernization and national revival in Uzbek society from a socio-philosophical perspective. The study highlights the role of spiritual renewal in strengthening national identity, restoring historical memory, transforming values, and fostering civic consciousness. It also examines the impact of national revival on contemporary modernization processes and reveals the dialectical relationship between traditions and innovations.

Keywords: spiritual modernization, national revival, social consciousness, historical memory, national identity, value transformation, spirituality, New Uzbekistan.

Introduction. In the context of globalization and digital transformation, spiritual modernization has become one of the key factors of social development. Any modernization process encompasses not only economic and political systems but also the spiritual life, values, and social consciousness of society. In this regard, the reforms being implemented in Uzbekistan are centered on human dignity, national self-awareness, and spiritual advancement.

Spiritual modernization is closely connected with national revival, and their relationship possesses a dialectical character. While national revival serves to restore historical memory and national values, spiritual modernization seeks to harmonize these values with the requirements of contemporary development. As a result, a new qualitative stage emerges in the interaction between traditional and modern values.

According to Academician A. Erkeyev, “the most important prerequisite for spiritual development is the awareness of national identity and its enrichment in accordance with the demands of modern progress” [1]. This view demonstrates that spiritual modernization and national revival are not mutually exclusive but rather complementary processes.

Socio-Philosophical Essence of Spiritual Modernization. Spiritual modernization refers to the renewal and improvement of society’s spiritual life in accordance with new historical conditions. This process involves not only changing values but also

enriching them with new meanings and adapting them to the needs of social development.

According to philosopher N. Juraev, every stage of historical development brings specific changes to a nation's spiritual image and social consciousness. These changes also reshape society's attitude toward its own history [2]. Therefore, spiritual modernization manifests itself as a synthesis of historical experience and contemporary needs.

Today, spiritual modernization in Uzbekistan is being implemented through the following directions:

- restoration and promotion of historical heritage;
- enrichment of national values with contemporary content;
- modernization of the education system;
- fostering patriotism and civic responsibility among youth;
- development of digital culture and information consumption culture.

These processes contribute to the formation of a new stage of spiritual development.

Philosophical Foundations of National Revival. National revival is the process of reinterpreting a society's historical memory, cultural heritage, and national identity. It strengthens a nation's relationship with its history, language, culture, and spiritual values.

Academician N. Komilov describes national revival as "the return of a people to its historical roots and the rediscovery of its national identity" [3]. During the years of independence, this process intensified significantly and initiated a new stage in the development of national consciousness.

The main manifestations of national revival in Uzbek society include:

- restoration of Jadid heritage;
- study of the scientific legacy of great scholars;
- preservation of historical monuments and cultural heritage;
- development of national customs and traditions;
- strengthening of national pride and patriotism.

These factors have become important components of the transformation of social consciousness.

The Dialectical Unity of Spiritual Modernization and National Revival. From a dialectical perspective, all development occurs through the unity and interaction of contradictions. Spiritual modernization and national revival are not opposing phenomena but rather mutually enriching and complementary processes.

On the one hand, national revival seeks to preserve historical heritage and traditions. On the other hand, spiritual modernization adapts these traditions to the requirements of contemporary development. Consequently, a dialectical balance emerges between tradition and innovation.

According to B. Ganiyev, one of the essential conditions for the development of modern society is the harmonization of national values with innovative progress [4]. This creates opportunities for active participation in global development processes while preserving national identity.

This principle is clearly reflected in the development strategy of New Uzbekistan. In particular, ongoing reforms aimed at preserving national heritage, equipping young people with modern knowledge and professional skills, developing an innovation-driven economy [5], and strengthening civil society demonstrate the dialectical unity of spiritual modernization and national revival.

Prospects for Spiritual Development in New Uzbekistan. The concept of New Uzbekistan is focused on promoting human dignity, spiritual growth, and civic engagement. Within this framework, spiritual modernization has become a strategic direction of national development.

According to A. Erkeyev, the future of spiritual development depends on the harmonization of national values with universal human principles [1]. In this context, the primary task of contemporary Uzbekistan is not only to preserve historical heritage but also to cultivate innovative thinking.

The effectiveness of future spiritual modernization will depend on several factors:

- improving the quality of education;
- supporting science and innovation;
- developing national culture;
- strengthening civil society;
- enhancing the spiritual resilience of youth.

Conclusion. The findings of this study demonstrate that the processes of spiritual modernization and national revival in Uzbek society are closely interconnected and possess a dialectical character. While national revival contributes to the restoration of historical memory, national identity, and cultural heritage, spiritual modernization enriches these values in accordance with the requirements of contemporary development.

The integration of these processes constitutes an important philosophical foundation for the development of New Uzbekistan. Furthermore, they contribute to the

transformation of social consciousness, the advancement of civic culture, and the sustainable development of the nation.

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TRAFİK AKIŞINI DEĞERLENDİRME YÖNTEMLERİ

**Taşkent Devlet Ulaştırma Üniversitesi Yüksek Lisans 1. Sınıf Öğrencisi
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Özet

Bu çalışmada, kentsel ulaşım altyapısında trafik akışlarını değerlendirmenin modern yöntemleri ve bunların etkinliği analiz edilmektedir. Trafik akış parametrelerinin (yoğunluk, hız ve hacim) belirlenmesinde geleneksel gözlem yöntemlerinden yapay zeka, video analitiği ve sensör verilerinin işlenmesi gibi ileri teknolojilerin rolü incelenmektedir. Araştırma kapsamında, ulaşım sistemlerinde meydana gelen trafik sıkışıklıklarını tahmin etmek, trafik güvenliğini sağlamak ve mevcut altyapıyı optimize etmek için en uygun matematiksel modellerin ve bilgi sistemlerinin uygulanması ele alınmıştır. Elde edilen sonuçlar, trafik akışını değerlendirmek için doğru yöntemlerin seçilmesinin, ulaşım ağının kapasitesini artırmada ve kentsel çevreyi ekolojik açıdan iyileştirmede ne kadar önemli olduğunu kanıtlamaktadır.

Anahtar Kelimeler: Trafik akışı, akış parametreleri, trafik modelleme, akıllı ulaşım sistemleri (ITS), trafik akışını optimize etme, altyapı verimliliği.

Giriş

Günümüzde kentsel ulaşım altyapısının sürdürülebilir kalkınması, doğrudan trafik akışlarını doğru ve etkin bir şekilde değerlendirme yöntemlerine bağlıdır. Şehir nüfusunun artması ve araç sayısının çoğalması, yol ağları üzerindeki yükü önemli ölçüde artırmış ve geleneksel değerlendirme yöntemlerinin imkanlarını kısıtlamıştır. Sonuç olarak, trafik sıkışıklığı, trafik kazaları ve çevre kirliliği gibi sorunlar güncelliğini koruyan meseleler haline gelmiştir.

Trafik akışlarını incelemek, ulaşım ağının kapasitesini artırmanın ve kentsel çevreyi vatandaşlar için konforlu ve güvenli hale getirmenin temel faktörüdür. Modern şartlarda trafik akışını değerlendirmek, sadece istatistiksel verileri toplamakla kalmayıp, aynı zamanda gerçek zamanlı hareket özelliklerini analiz etmeyi de gerektirir. Bu çalışmanın amacı; trafik akışının temel parametrelerini (hız, yoğunluk ve akış hacmi) belirlemede modern bilgi-iletişim teknolojilerinin, yapay zekanın ve matematiksel modellerin kullanımını analiz etmektir. Bu yaklaşımlar, ulaşım sistemini "akıllı" yönetmenin ve altyapıyı dijital dönüştürmenin teknolojik temelini oluşturur.

Ana bölüm

Trafik Akışını Değerlendirme Yöntemleri



Kentsel trafik akışını analiz ederken birkaç düzeydeki modeller kullanılır: makroskopik (akış, yoğunluk ve hız gibi grup göstergelerine dayalı modeller), mezoskopik (grup hareketini, ancak bazı grup özelliklerini de dikkate alan modeller) ve mikroskopik (bireysel araçların ve sürücülerin davranışlarını analiz eden modeller). Örneğin, makroskopik modelde yol üzerindeki araç akışı sıvı dinamiğine benzetilerek ifade edilir, mezoskopik model belirli grupların etkileşimini tahmini olarak yansıtır, mikroskopik model ise araçlar arası takip mesafesi, hızlanma-frenleme ve şerit değiştirme gibi davranışları hesaplar.

Trafik ölçüm yöntemleri şunları içerir:

Manuel veya otomatik trafik sayıcılar: Yayaların, araçların ve toplu taşıma araçlarının hareketini (örneğin, taşıma hacmini) hesaplamak için pnömatik tüpler, radar, endüktif döngüler (looplar), video analitiği veya sensörler kullanılır. Trafik yoğunluğu ve hızı, gerçek zamanlı olarak genellikle sensörlerle ölçülür.

Köken-Hedef (OD) anketleri: Yolculara nereden nereye gittikleri sorulur (bu bilgiler mülakatlar, çevrimiçi uygulamalar veya toplu taşıma araçlarında yapılan anketler yoluyla elde edilebilir). Bu, şehirlerarası hareket yönlerini belirlemeye hizmet eder.

GPS/AVL ve mobil telefon verileri: Toplu taşıma araçlarına veya yük kamyonlarına yerleştirilen GPS cihazlarından ya da insanların mobil cihazlarındaki GPS ve GSM sinyal konum verilerinden yararlanılır. Bu yöntem, büyük hacimli gerçek zamanlı hareket verileri sağlayabilir.

Buna örnek olarak, Yandex.Maps uygulamasında Özbekistan'ın 13 şehrinde (230 güzergahta) otobüsleri gerçek zamanlı izleme fonksiyonunun devreye alınması gösterilebilir; bu, yolcuların seferlerini önceden planlamalarına olanak tanır.

Otomatik sensör ağları (Akıllı Şehir teknolojileri): Yoldaki trafik yoğunluğunu, hızı ve hatta hava durumunu aynı anda kaydedebilen akıllı sensör sistemleri yaygınlaşmaktadır. Örneğin, akıllı trafik ışıkları sayesinde güzergah süresinden 25–30 % a kadar tasarruf etmek mümkündür. Dijital ikiz konsepti temelinde oluşturulan şehir modellerinde ise altyapı projelerini önceden değerlendirmeye olanak tanıyan teknolojiler kullanılır.

Seyahat talep modelleri ve simülasyon: Kentsel ulaşımı planlarken genellikle dört aşamalı talep modeli (araç sahipliği oranı, yola çıkma eğilimi, güzergah dağılımı, ulaşım türlerine ayrılma) kullanılır. Bu tür modellerde nüfusun konut, iş saati, ulaşım hizmetleri coğrafyası girilerek günlük hareket alışkanlıkları değerlendirilir. Simülasyon araçları (PTV Vissim, Visum, Aimsun, Cube, Emme ve açık kaynaklı SUMO, MATSim gibi) aracılığıyla gerçek koşullara benzer şehir yollarının sanal

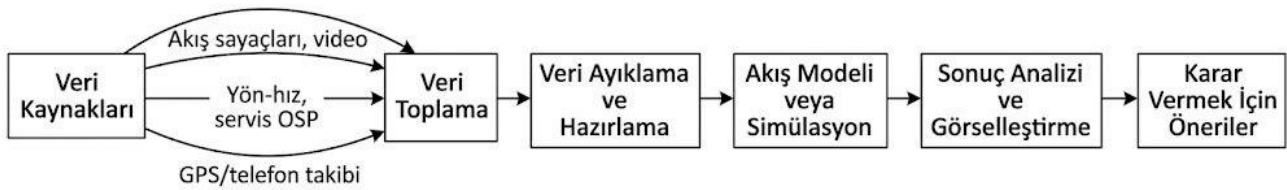
reprodüksiyonu gerçekleştirilir ve çeşitli öneri ve çevre değişiklikleri test edilir. Örneğin, Taşkent'teki Çilonzor kavşağında yürütülen projede, altyapıyı yeniden tasarlama ve trafik ışığı ayarlarını optimize etme çalışmaları PTV Vissim ile test edilmiş, trafik sıkışıklığını azaltma ve güvenliği artırma etkileri belirlenmiştir.

İstatistiksel ve yapay zeka yaklaşımları: Büyük veri sistemleri ve makine öğrenimi algoritmaları, trafik akışını tahmin etmede kullanılmaktadır. Örneğin, dış veri tabanları (Google Maps trafik ve hava durumu verileri) temelinde oluşturulan CNN-LSTM derin öğrenme modeli, kısa vadeli trafik sıkışıklığı seviyelerini tahmin etmede yüksek doğruluk oranları vermiştir. Bu tür yaklaşımlar, mekansal-zamansal modelleri belirleme ve dinamik faktörleri (örneğin, hava durumu veya tatil günleri) hesaba katma imkanı sağlar.

Bilgi akışı (akış şeması)

Trafik akışını değerlendirme süreçleri, bilgi toplamadan analize kadar birbirine bağlı aşamalardan oluşur. Örneğin, aşağıdaki diyagramında temel aşamalar gösterilmektedir:

- Bu süreçlerde ekonomik, istatistiksel ve mühendislik verileri kaynaklardan alınır ve çeşitli modeller (makroskobik, mikroskobik, makine öğrenmesi) temelinde işlenir.
- Diyagramdaki aşamalar, Cumhurbaşkanlığı kararnamesinin gerekliliklerinde belirtildiği üzere, matematiksel modelleme ve dijital çözümler kullanılarak trafik akışını yönetmek için gereklidir.



Sonuç

Ulaşım sektöründeki mevcut sorunları çözmek için tüm tarafların ortak hareket etmesi gerekmektedir. Özel çalışma grupları oluşturulmalı ve hükümet, şehir yöneticileri, uzmanlar ve kamuoyu arasında koordinasyon sağlanmalıdır. Örneğin, Cumhurbaşkanı kararnamesinde "bilimsel yaklaşım temelinde" geliştirilen ulaşım şemalarının ve dijital sistemlerin uygulamaya konulması talimatı verilmiştir (örneğin, "yolcu ve yaya akışlarının matematiksel modellenmesi"). Bu durum, kurumlar arası iş birliğini ve nitelikli uzmanların yetiştirilmesini gerektirir.

Özbekistan'da şehir içi trafik akışını değerlendirmek için mevcut kaynaklar; resmi istatistiksel veriler (Ulaştırma Bakanlığı ve İstatistik Ajansı raporları), trafik polisi ve

toplu taşıma operatörlerinin istatistikleri ile yeni dijital sistemlerden (GPS/otobüs izleme, mobil uygulamalar) elde edilmektedir. Büyük şehirlerde Yandex gibi uygulamalar aracılığıyla büyük hacimli verilerin toplandığı gözlemlenmektedir, ancak bunlar da bazı durumlarda sınırlıdır. Aynı zamanda, veri entegrasyonu ve ticari amaçlı verilerin kullanımı gibi alanlarda yasal zorlukların olduğu da kabul edilmektedir.

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Kreativ fikrlashni rivojlantirishda san'at va madaniyatning roli

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Annotatsiya:

Ushbu ilmiy maqolada kreativ fikrlashni rivojlantirishda san'at va madaniyatning tutgan o'rni tahlil qilinadi. San'atning turli yo'nalishlari — musiqa, tasviriy san'at, adabiyot va teatrning inson tafakkuri hamda ijodiy salohiyatiga ta'siri yoritib berilgan. Shuningdek, milliy va umuminsoniy madaniy qadriyatlarning shaxsning erkin va innovatsion fikrlashini shakllantirishdagi ahamiyati ochib beriladi. Maqolada ta'lim jarayonida san'at va madaniyat elementlaridan foydalanish orqali o'quvchilarning kreativ qobiliyatlarini rivojlantirishning samarali usullari ilmiy asosda tahlil qilingan.

Kalit so'zlar:

Kreativ fikrlash, san'at, madaniyat, ijodkorlik, estetik tarbiya, innovatsion yondashuv, tasavvur, badiiy tafakkur, ta'lim jarayoni, madaniy qadriyatlar, ijodiy faoliyat, pedagogik texnologiyalar.

Kirish

Bugungi globallashuv va tezkor texnologik taraqqiyot davrida insonning ijodiy salohiyati, ya'ni kreativ fikrlashi jamiyat rivojlanishining muhim omillaridan biriga aylanmoqda. Kreativ fikrlash nafaqat yangi g'oyalarni yaratish, balki mavjud muammolarga noodatiy va samarali yechim topish qobiliyati sifatida ham e'tirof etiladi. Shu nuqtayi nazardan, ta'lim tizimida va shaxs rivojlanishida kreativ fikrlashni shakllantirish masalasi dolzarb ahamiyat kasb etadi. San'at va madaniyat esa inson tafakkurini boyituvchi, estetik didini shakllantiruvchi hamda ijodiy tasavvurini kengaytiruvchi eng muhim vositalardan biri hisoblanadi. Musiqa, tasviriy san'at, adabiyot, teatr va boshqa madaniy yo'nalishlar insonning emotsional va intellektual rivojlanishiga bevosita ta'sir ko'rsatib, uning ijodiy fikrlash jarayonini faollashtiradi. Ayniqsa, san'at bilan muntazam shug'ullanish yoki madaniy muhitda bo'lish shaxsning noodatiy fikrlash, tahlil qilish va yangilik yaratish qobiliyatini rivojlantiradi. Shu sababli, ushbu ilmiy maqolada san'at va madaniyatning kreativ fikrlashni



rivojlantirishdagi o'rni, ularning shaxs intellektual va ijodiy salohiyatiga ta'siri hamda ta'lim jarayonida bu omillardan samarali foydalanish imkoniyatlari tahlil qilinadi.

Asosiy qism

Kreativ fikrlash insonning muammolarga yangicha yondashish, noan'anaviy yechimlar topish va mavjud bilimlarni yangi shaklda qo'llay olish qobiliyatidir. Ushbu jarayon faqatgina tabiiy iste'dodga emas, balki tashqi muhit, tarbiya va madaniy-ijodiy faoliyatga ham chambarchas bog'liqdir. Ayniqsa, san'at va madaniyat insonning fikrlash doirasini kengaytirishda, tasavvur va fantaziyasini rivojlantirishda muhim rol o'ynaydi.

San'at inson ongiga bevosita emotsional ta'sir ko'rsatadi. Musiqa, tasviriy san'at, adabiyot va teatr kabi yo'nalishlar orqali inson turli his-tuyg'ularni boshdan kechiradi va ularni tahlil qilishga o'rganadi. Bu esa miyada yangi neyron bog'lanishlar shakllanishiga yordam beradi, natijada ijodiy fikrlash jarayoni faollashadi. Masalan, musiqani tinglash yoki rasm chizish jarayonida inson tasavvuri kengayadi va u oddiy narsalarga ham boshqacha nigoh bilan qaray boshlaydi. Madaniyat esa shaxsning dunyoqarashi va tafakkurini shakllantiruvchi asosiy omillardan biridir. Turli xalqlarning madaniy merosi bilan tanishish insonni bir yoqlama fikrlashdan xalos qiladi va ko'p qirrali yondashuvni rivojlantiradi. Madaniy muhitda o'sib-ulg'aygan shaxs odatda ochiq fikrli, yangilikka intiluvchan va muammolarni turli tomondan tahlil qila oladigan bo'ladi. Ta'lim jarayonida san'at va madaniyat elementlaridan foydalanish kreativ fikrlashni rivojlantirishda juda samarali usul hisoblanadi. Interfaol darslar, ijodiy topshiriqlar, teatr sahnalari yoki badiiy loyihalar o'quvchilarning faolligini oshiradi va ularni mustaqil fikrlashga undaydi. Shuningdek, guruh bo'lib ishlash jarayonida ham o'quvchilarda hamkorlik, muloqot va birgalikda yechim topish ko'nikmalari rivojlanadi.

Bundan tashqari, zamonaviy pedagogik yondashuvlar san'atni faqat estetik vosita sifatida emas, balki ta'limning ajralmas qismi sifatida ko'rib chiqmoqda. Kreativ laboratoriyalar, san'at terapiyasi va loyiha asosidagi ta'lim kabi usullar o'quvchilarning ijodiy salohiyatini ochishga xizmat qilmoqda. Umuman olganda, san'at va madaniyat insonning ichki dunyosini boyitadi, uning tasavvurini kengaytiradi va yangi g'oyalar yaratish qobiliyatini kuchaytiradi. Shu bois, kreativ fikrlashni rivojlantirishda ushbu ikki omilning o'rni beqiyos hisoblanadi.

Innovatsion yondashuv



Kreativ fikrlashni rivojlantirish jarayonida innovatsion yondashuvlar san'at va madaniyatni ta'lim tizimiga samarali integratsiya qilishning zamonaviy usullaridan biri hisoblanadi. Bugungi kunda an'anaviy o'qitish usullari bilan bir qatorda raqamli texnologiyalar, interfaol platformalar va ijodiy laboratoriyalar orqali o'quvchilarning ijodiy salohiyatini ochishga alohida e'tibor qaratilmoqda. Innovatsion yondashuvning asosiy yo'nalishlaridan biri — raqamli san'at va multimedia vositalaridan foydalanishdir. Grafik dizayn dasturlari, animatsiya, virtual muzeylar va onlayn galereyalar o'quvchilarga san'atni faqat tomosha qilish emas, balki uni yaratish imkonini ham beradi. Bu esa ularning tasavvurini kengaytirib, ijodiy fikrlash jarayonini yanada faollashtiradi. Shuningdek, loyiha asosida o'qitish (project-based learning) ham muhim innovatsion yondashuvlardan biridir. Ushbu usulda o'quvchilar real hayotga yaqin ijodiy loyihalar ustida ishlaydi, masalan, madaniy merosni o'rganish, san'at ko'rgazmasi tashkil etish yoki ijodiy kontent yaratish. Bunday faoliyat ularni mustaqil fikrlashga, muammolarni tahlil qilishga va jamoada ishlashga o'rgatadi. San'at va madaniyatni o'qitishda gamifikatsiya (o'yinlashtirish) elementlaridan foydalanish ham samarali natija beradi. O'yin elementlari orqali berilgan topshiriqlar o'quvchilarning qiziqishini oshiradi va ularni faol ishtirok etishga undaydi. Bu esa bilimni o'zlashtirish jarayonini yanada qiziqarli va samarali qiladi. Bundan tashqari, sun'iy intellekt va virtual reallik texnologiyalarining ta'lim jarayoniga kirib kelishi ham innovatsion yondashuvning yangi bosqichini belgilab bermoqda. Virtual muzey sayohatlari, interaktiv san'at darslari va AI asosida yaratilgan ijodiy platformalar o'quvchilarning san'atga bo'lgan qiziqishini oshiradi hamda ularning kreativ fikrlashini rivojlantiradi. Xulosa qilib aytganda, innovatsion yondashuvlar san'at va madaniyatni ta'lim jarayoniga chuqur integratsiya qilish orqali kreativ fikrlashni rivojlantirishda muhim rol o'ynaydi. Bu esa zamonaviy, mustaqil fikrlaydigan va ijodkor shaxslarni tarbiyalashga xizmat qiladi.

Badiiy tafakkur

Badiiy tafakkur — bu insonning voqelikni obrazlar, tasavvurlar va emotsional ifodalar orqali anglash va ifoda etish qobiliyatidir. U oddiy mantiqiy fikrlashdan farqli ravishda, hissiyot, estetik idrok va ijodiy tasavvur bilan chambarchas bog'liq bo'lib, shaxsning kreativ salohiyatini shakllantirishda muhim o'rin tutadi. Badiiy tafakkur orqali inson dunyoni nafaqat tushunadi, balki uni o'zicha qayta yaratadi va yangicha talqin qiladi. San'at badiiy tafakkurning eng asosiy manbalaridan biri hisoblanadi. Tasviriylar san'at,



adabiyot, musiqa va teatr kabi yo'nalishlar inson ongida obrazli fikrlashni rivojlantiradi. Masalan, adabiy asarlarni o'qish jarayonida o'quvchi qahramonlar obrazini tasavvur qiladi, ularning his-tuyg'ularini his etadi va voqealarni ichki dunyosi orqali qayta ishlaydi. Bu jarayon miyada ijodiy fikrlashni faollashtirib, yangi g'oyalar shakllanishiga yordam beradi. Badiiy tafakkur shaxsning estetik didini ham rivojlantiradi. Inson go'zallikni his qilishni o'rganar ekan, u atrofdagi voqea-hodisalarga yanada chuqurroq va nozikroq yondasha boshlaydi. Bu esa uning ijodiy qaror qabul qilish qobiliyatini kuchaytiradi hamda noodatiy yechimlar topishga undaydi. Ta'lim jarayonida badiiy tafakkurni rivojlantirish muhim pedagogik vazifalardan biri hisoblanadi. Rasm chizish, ijodiy yozuvlar, sahna ko'rinishlari va musiqa bilan bog'liq mashg'ulotlar o'quvchilarning tasavvurini kengaytiradi va ularni erkin fikrlashga o'rgatadi. Shu bilan birga, guruhli ijodiy ishlar ham muloqot, hamkorlik va fikr almashish ko'nikmalarini rivojlantiradi. Xulosa qilib aytganda, badiiy tafakkur insonning ijodiy rivojlanishida muhim asos bo'lib xizmat qiladi. U san'at va madaniyat orqali shakllanib, shaxsning kreativ fikrlash darajasini yangi bosqichga olib chiqadi.

Xulosa

Xulosa qilib aytganda, kreativ fikrlashni rivojlantirishda san'at va madaniyatning o'rni beqiyosdir. Ular insonning badiiy tafakkurini shakllantirib, tasavvur doirasini kengaytiradi hamda yangicha g'oyalar yaratish qobiliyatini rivojlantiradi. San'atning emotsional va estetik ta'siri, madaniyatning esa dunyoqarashni boyituvchi jihatlari shaxsning ijodiy salohiyatini faollashtiradi. Zamonaviy ta'lim jarayonida san'at va madaniyat elementlaridan foydalanish o'quvchilarning mustaqil fikrlash, muammolarni noodatiy yo'l bilan hal qilish va innovatsion yondashuvlarni shakllantirishiga xizmat qiladi. Ayniqsa, interfaol metodlar, loyiha asosidagi ta'lim va raqamli texnologiyalar bu jarayonni yanada samarali qiladi. Umuman olganda, san'at va madaniyatni ta'lim va tarbiya jarayoniga keng joriy etish kreativ fikrlashni rivojlantirishning muhim omillaridan biri bo'lib, bu kelajakda ijodkor, tashabbuskor va raqobatbardosh shaxslarni shakllantirishga zamin yaratadi.

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THE SOCIO-PHILOSOPHICAL ESSENCE AND THEORETICAL FOUNDATIONS OF THE PHENOMENON OF LEGAL NIHILISM

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Abstract. Legal nihilism is one of the most significant obstacles to the establishment of the rule of law and democratic governance. It manifests itself through distrust of legal institutions, disregard for legal norms, and skepticism regarding the effectiveness of law as a regulator of social relations. This study examines the socio-philosophical essence of legal nihilism, its theoretical foundations, causes, and social consequences. The research relies on the works of Uzbek and CIS scholars in the fields of legal philosophy, legal culture, and state theory.

Keywords: legal nihilism, legal consciousness, legal culture, rule of law, social philosophy, civil society.

Introduction. The modernization of society and the establishment of democratic governance require a high level of legal culture and legal consciousness among citizens. However, in many transitional societies, legal norms are often perceived as ineffective or detached from social realities. Such conditions contribute to the emergence of legal nihilism, which weakens the authority of law and undermines public trust in state institutions.

According to S.S. Alekseev, legal nihilism reflects a negative attitude toward law and legal values, arising from deficiencies in legal culture and legal awareness [1]. The phenomenon becomes particularly visible when legal norms fail to correspond with social expectations and practical realities.

Theoretical Foundations of Legal Nihilism. The term “nihilism” derives from the Latin word *nihil*, meaning “nothing.” In philosophy, nihilism signifies the rejection of established norms, values, and institutions. Legal nihilism is a specific form of this phenomenon directed toward law and legal institutions.

N.A. Berdyaev considered nihilism a socio-cultural response to crises of values and moral disorientation [2]. He argued that the rejection of legal and moral norms often emerges when individuals lose confidence in the legitimacy of social institutions.

Russian legal scholar V.V. Lazarev defines legal nihilism as a deformation of legal consciousness characterized by disbelief in the effectiveness and social value of law

[3]. Similarly, N.I. Matuzov emphasizes that legal nihilism represents a destructive attitude toward legal order and constitutional principles [4].

In Uzbek legal scholarship, A.X. Saidov notes that legal nihilism develops where legal culture remains insufficiently developed and where citizens do not perceive law as an instrument for protecting their rights and interests [5].

Socio-Philosophical Nature of Legal Nihilism. From a socio-philosophical perspective, legal nihilism is not merely a legal phenomenon but also a reflection of broader social contradictions. It arises from the interaction between social consciousness, institutional practices, and cultural values.

D.A. Kerimov argues that legal consciousness is inseparable from social consciousness and reflects society's perceptions of justice, legality, and social order [6]. Consequently, distortions in legal consciousness often produce nihilistic attitudes toward law.

Legal nihilism may be understood through several dimensions:

- cognitive (lack of legal knowledge);
- axiological (devaluation of legal values);
- behavioral (non-compliance with legal norms);
- institutional (disregard for legal principles by public authorities).

These dimensions demonstrate that legal nihilism possesses both individual and collective characteristics.

Causes of Legal Nihilism. Researchers identify several factors contributing to the emergence of legal nihilism:

- ineffective implementation of legislation;
- corruption and bureaucratic arbitrariness;
- inconsistency between legal norms and social realities;
- weak legal education;
- low levels of civic participation;
- historical traditions of authoritarian governance [7].

According to H.T. Odilqoriyev, legal nihilism often develops when citizens perceive a discrepancy between declared legal principles and actual governmental practices [8]. Such contradictions diminish trust in legal institutions and encourage informal forms of social regulation.

Legal Culture as a Means of Overcoming Legal Nihilism. Most contemporary scholars regard legal culture as the primary mechanism for combating legal nihilism. Legal culture promotes respect for law, strengthens civic responsibility, and facilitates the internalization of legal values.

Z.M.Islomov emphasizes that legal culture constitutes an essential component of democratic transformation and social modernization [9]. Through legal education and civic engagement, societies can develop positive attitudes toward law and constitutional principles.

Therefore, the formation of a mature legal culture represents a necessary condition for reducing the prevalence of legal nihilism and strengthening the rule of law.

Conclusion. Legal nihilism is a complex socio-philosophical phenomenon rooted in deficiencies of legal culture, crises of social trust, and contradictions between legal norms and social realities. The works of Uzbek and CIS scholars demonstrate that legal nihilism threatens democratic development and the effectiveness of legal institutions. The successful prevention of legal nihilism requires comprehensive reforms aimed at improving legal education, strengthening legal culture, enhancing institutional transparency, and ensuring the consistent implementation of legal norms. Only under such conditions can law function as a respected and effective regulator of social relations.

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**TiO₂ NANO ZARRACHALARI ASOSIDA FOTOKATALITIK VA
YORUG‘LIKNI QAYTARUVCHI XOSSALARGA EGA INNOVATSION
BO‘YOQLAR YARATISH**

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Annotatsiya: Ushbu ishda titan dioksid (TiO₂) nanozarrachalari asosida fotokatalitik va yorug‘likni qaytaruvchi xossalarga ega innovatsion bo‘yoqlarni yaratish va ularning fizik-kimyoviy xususiyatlarini o‘rganish masalasi yoritilgan. Tadqiqotda TiO₂ nanozarrachalarining yuqori sirt faolligi, keng tarmoqli yarimo‘tkazgich xususiyati hamda ultrabinafsha (UV) nurlanish ta’sirida fotokatalitik reaksiyalarni faollashtirish qobiliyati asosiy ilmiy asos sifatida ko‘rib chiqiladi. Shuningdek, ushbu nanozarrachalarning organik ifloslantiruvchi moddalarni parchalanishida va o‘z-o‘zini tozalovchi (self-cleaning) yuzalar yaratishdagi roli tahlil qilinadi. Innovatsion bo‘yoqlar tarkibiga kiritilgan TiO₂ nanozarrachalari nafaqat yorug‘likni yuqori darajada qaytarish, balki issiqlik yutilishini kamaytirish orqali energiya samaradorligini oshirish imkonini beradi. Tadqiqot natijalari ekologik toza, uzoq xizmat qiluvchi va ko‘p funksiyali qoplama materiallarini ishlab chiqishda muhim ahamiyatga ega ekanligini ko‘rsatadi.

Kalit so‘zlar: TiO₂ nanozarrachalari, fotokataliz, innovatsion bo‘yoqlar, yorug‘likni qaytarish, ultrabinafsha nurlanish, self-cleaning qoplamalar, nanomateriallar, energiya samaradorligi, ekologik toza materiallar, yarimo‘tkazgich xossalari.

Abstract: This study focuses on the development of innovative coatings based on titanium dioxide (TiO₂) nanoparticles with photocatalytic and light-reflecting properties, as well as the investigation of their physicochemical characteristics. The research examines the fundamental properties of TiO₂ nanoparticles, including their high surface activity, wide band-gap semiconductor behavior, and ability to initiate photocatalytic reactions under ultraviolet (UV) irradiation. In particular, the role of these nanoparticles in the degradation of organic pollutants and in the creation of self-cleaning surfaces is analyzed. Incorporation of TiO₂ nanoparticles into coating

formulations enables not only high light reflectance but also improved energy efficiency by reducing heat absorption. The results demonstrate that such nanostructured coatings are promising for the development of environmentally friendly, durable, and multifunctional surface materials with potential applications in construction, industry, and environmental protection.

Keywords: TiO₂ nanoparticles, photocatalysis, innovative coatings, light reflection, ultraviolet radiation, self-cleaning surfaces, nanomaterials, energy efficiency, environmentally friendly materials, semiconductor properties.

Аннотация: В данной работе рассматривается разработка инновационных покрытий на основе наночастиц диоксида титана (TiO₂), обладающих фотокаталитическими и светоотражающими свойствами, а также исследование их физико-химических характеристик. Особое внимание уделяется фундаментальным свойствам наночастиц TiO₂, включая их высокую поверхностную активность, широкозонную полупроводниковую природу и способность инициировать фотокаталитические реакции под воздействием ультрафиолетового (УФ) излучения. В частности, анализируется роль данных наночастиц в разложении органических загрязнителей и формировании самоочищающихся поверхностей. Введение наночастиц TiO₂ в состав покрытий позволяет не только обеспечить высокую отражательную способность, но и повысить энергоэффективность за счёт снижения поглощения тепла. Полученные результаты показывают перспективность таких наноструктурированных покрытий для создания экологически безопасных, долговечных и многофункциональных материалов, применяемых в строительстве, промышленности и экологической защите.

Ключевые слова: Наночастицы TiO₂, фотокатализ, инновационные покрытия, светоотражение, ультрафиолетовое излучение, самоочищающиеся поверхности, наноматериалы, энергоэффективность, экологически чистые материалы, полупроводниковые свойства.

Kirish: So‘nggi yillarda nanomateriallar asosida yaratilayotgan funksional qoplamalar va bo‘yoqlar ilm-fan hamda sanoatning eng jadal rivojlanayotgan yo‘nalishlaridan biriga aylangan. Ayniqsa, titan dioksid (TiO_2) nanozarrachalari asosidagi tizimlar o‘zining noyob fizik-kimyoviy xossalari bilan katta e‘tibor qozonmoqda. Ushbu material yuqori fotokatalitik faolligi, kimyoviy barqarorligi, toksik emasligi hamda kuchli yorug‘likni sochish va qaytarish xususiyati bilan ajralib turadi. Shu sababli TiO_2 nanozarrachalari ekologik toza, energiya tejankor va ko‘p funksiyali bo‘yoqlar yaratishda muhim asosiy komponent sifatida qaralmoqda. Hozirgi globallashuv va sanoatlashuv jarayonida atrof-muhit ifloslanishi, energiya resurslaridan samarasiz foydalanish hamda urbanizatsiya natijasida yuzaga kelayotgan issiqlik “orol” effekti kabi muammolar dolzarb ahamiyat kasb etmoqda. Bunday sharoitda o‘z-o‘zini tozalovchi, havoni qisman tozalovchi va quyosh nurlarini qaytaruvchi qoplamalarga ehtiyoj ortib bormoqda. TiO_2 nanozarrachalari asosidagi fotokatalitik bo‘yoqlar esa ultrabinafsha nurlanish ta’sirida organik ifloslantiruvchi moddalarni parchalay olish xususiyati tufayli ushbu muammolarni hal etishda istiqbolli yechim sifatida ko‘rilmoqda. Ilmiy tadqiqotlar shuni ko‘rsatadiki, TiO_2 nanozarrachalarining o‘lchami nanometr darajasiga tushirilganda ularning sirt faolligi sezilarli darajada ortadi, bu esa fotokatalitik jarayonlarning samaradorligini oshiradi. Shu bilan birga, ushbu zarrachalar yorug‘likni kuchli sochib, qoplamalarning yuqori darajada oq va yorug‘likni qaytaruvchi bo‘lishini ta’minlaydi. Natijada, bunday bo‘yoqlar binolar va inshootlarning qizishini kamaytirib, energiya sarfini qisqartirishga xizmat qiladi. Ushbu ishning asosiy maqsadi TiO_2 nanozarrachalari asosida fotokatalitik va yorug‘likni qaytaruvchi xossalarga ega innovatsion bo‘yoqlarni yaratish imkoniyatlarini o‘rganish hamda ularning amaliy qo‘llanilish istiqbollarini tahlil qilishdan iboratdir. Tadqiqot natijalari ekologik xavfsiz, uzoq muddat xizmat qiluvchi va yuqori samaradorlikka ega yangi avlod qoplama materiallarini ishlab chiqishda muhim ilmiy-amaliy ahamiyat kasb etadi.

ASOSIY QISM

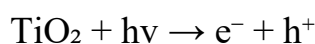
1. TiO_2 nanozarrachalarining fizik-kimyoviy xossalari

Titan dioksid (TiO_2) nanozarrachalari yarimo‘tkazgich materiallar sinfiga mansub bo‘lib, keng energetik band oralig‘iga ega (taxminan 3.0–3.2 eV). Ushbu xususiyat uning ultrabinafsha nurlanishni yutish va fotokatalitik jarayonlarni faollashtirish qobiliyatini belgilaydi. Nano o‘lchamga ega bo‘lishi esa materialning solishtirma yuzasini keskin oshiradi, natijada reaksiya faolligi yuqori darajaga chiqadi. TiO_2 asosan uchta kristall shaklda uchraydi: anataz, rutil va brookit. Ular ichida anataz fazasi fotokatalitik faolligi jihatidan eng samarali hisoblanadi. Rutil esa yuqori barqarorlik va

yorug'likni qaytarish xususiyati bilan ajralib turadi. Shu sababli innovatsion bo'yoqlar tarkibida ushbu fazalarning kombinatsiyasi optimal natija beradi. Nanozarrachalarning yuzasida elektron–teshik juftlarining hosil bo'lishi fotokatalitik jarayonlarning asosini tashkil etadi. Bu jarayon natijasida faol kislorod turlari ($\bullet\text{OH}$, O_2^-) hosil bo'lib, ular organik ifloslantiruvchi moddalarni oksidlab parchalaydi.

2. Fotokatalitik mexanizm va uning ishlash prinsipi

TiO_2 asosidagi fotokataliz jarayoni ultrabinafsha nurlanish ta'sirida boshlanadi. Fotonning yutilishi natijasida elektronlar valent zonadan o'tkazuvchanlik zonasiga o'tadi va elektron–teshik juftlari hosil bo'ladi:



Hosil bo'lgan zaryad tashuvchilar atrof-muhitdagi suv va kislorod bilan reaksiyaga kirishib, yuqori reaktiv radikallarni hosil qiladi. Ushbu radikallar esa bakteriyalar, organik ifloslantiruvchilar va zararli gazlarni parchalaydi. Natijada sirt o'z-o'zini tozalash xususiyatiga ega bo'ladi. Bu xossa “self-cleaning” texnologiyalarida, ayniqsa, qurilish materiallari va tashqi qoplamalarda juda muhim hisoblanadi.

3. Yorug'likni qaytaruvchi (reflektiv) xossalalar

TiO_2 nanozarrachalari yuqori sindirish ko'rsatkichiga ega bo'lgani uchun yorug'likni kuchli sochish va qaytarish xususiyatiga ega. Bu bo'yoqlarning optik xossalari yaxshilaydi va ularga yuqori darajadagi oqlik beradi. Reflektiv qoplamalar quyosh nurlarini qaytarish orqali yuzaning qizishini kamaytiradi. Bu esa bino va inshootlarda issiqlik yuklamasini pasaytiradi hamda sovutish tizimlariga bo'lgan energiya sarfini kamaytiradi. Shu sababli bunday bo'yoqlar “cool coating” texnologiyalarida keng qo'llaniladi.

4. Innovatsion bo'yoqlar tarkibi va tayyorlash texnologiyasi

Innovatsion bo'yoqlarni yaratishda TiO_2 nanozarrachalari asosiy faol komponent sifatida polimer bog'lovchi moddalarga (akril, epoksi yoki poliuretan asosli) qo'shiladi. Zarrachalarning bir tekis taqsimlanishi bo'yoqning samaradorligini belgilovchi asosiy omil hisoblanadi. Dispersiya jarayonida ultratovushli aralashtirish yoki sirt-faol moddalardan foydalanish nanozarrachalarning aglomeratsiyasini oldini oladi. Bu esa materialning fotokatalitik faolligini va optik bir xilligini oshiradi.

5. *Qo'llanilish sohalari va amaliy ahamiyati*

TiO₂ nanozarrachalari asosidagi bo'yoqlar keng ko'lamli amaliy sohalarda qo'llaniladi. Ular quyidagi yo'nalishlarda katta ahamiyatga ega:

Qurilish sanoatida o'z-o'zini tozalovchi fasadlar yaratish

Shahar infratuzilmasida havo tozalovchi yuzalar

Avtomobil sanoatida issiqlikni kamaytiruvchi qoplamalar

Tibbiyotda antibakterial yuzalar yaratish

Energiya tejamkor "aqlli" binolar qurilishi

Ushbu xossalar ularni zamonaviy ekologik muammolarni hal etishda muhim innovatsion materialga aylantiradi.

6. *Ekologik va iqtisodiy samaradorlik*

TiO₂ asosidagi qoplamalar ekologik xavfsiz bo'lib, uzoq muddatli foydalanishda atrof-muhitga zarar yetkazmaydi. Ular havodagi zararli birikmalarni kamaytirish orqali ekologik muvozanatni yaxshilaydi. Iqtisodiy jihatdan esa, energiya sarfini kamaytirish va yuzalarning uzoq vaqt toza saqlanishi hisobiga ekspluatatsiya xarajatlarini sezilarli darajada qisqartiradi. Bu esa ularni sanoat va qurilish uchun juda foydali qiladi.

TADQIQOT METODOLOGIYASI

1. *Tadqiqotning umumiy yondashuvi*

Ushbu ilmiy ish TiO₂ nanozarrachalari asosida fotokatalitik va yorug'likni qaytaruvchi xossalarga ega innovatsion bo'yoqlarni yaratish hamda ularning funksional xususiyatlarini o'rganishga qaratilgan. Tadqiqotda kompleks yondashuv qo'llanilib, nazariy tahlil va eksperimental tadqiqotlar birgalikda amalga oshiriladi. Asosiy maqsad materialning nanostruktura darajasidagi xossalarini uning makroskopik qoplama sifatidagi ishlash samaradorligi bilan bog'lashdir. Tadqiqot "tuzilma–xossa–samaradorlik" tamoyiliga asoslanadi, ya'ni materialning ichki tuzilishi uning fizik-kimyoviy xossalarini va amaliy qo'llanilish samaradorligini belgilab beradi.

2. *Ishlatilgan materiallar va reagentlar*

Tadqiqot jarayonida yuqori tozalikdagi TiO_2 nanozarrachalari asosiy faol komponent sifatida ishlatiladi. Bundan tashqari polimer bog'lovchi moddalar sifatida akril, epoksi yoki poliuretan asosidagi smolalar tanlanadi. Bo'yoq tarkibini barqarorlashtirish uchun dispersiyalovchi qo'shimchalar va sirt-faol moddalar qo'llaniladi. Erituvchi muhit sifatida suv yoki organik erituvchilar ishlatiladi. Zaruratga qarab ZnO , Ag yoki SiO_2 kabi qo'shimcha nanozarrachalar ham kompozitsiyaga kiritilishi mumkin. Materiallar ekologik xavfsizlik, kimyoviy barqarorlik va texnologik moslik asosida tanlanadi.

3. Nanozarrachalarni tayyorlash va ularni faollashtirish

Agar tayyor TiO_2 nanozarrachalari ishlatilmasa, ular sol-gel yoki gidrotermal usullar orqali sintez qilinadi. Sintez jarayonida zarracha o'lchami, kristall tuzilishi va sirt xususiyatlari qat'iy nazorat qilinadi. Nanozarrachalarning samaradorligini oshirish uchun ularning sirtini modifikatsiya qilish amalga oshiriladi. Bunda silan birikmalari yoki organik qoplamalar yordamida zarrachalar yuzasi faollashtiriladi va ularning aglomeratsiyaga moyilligi kamaytiriladi.

4. Innovatsion bo'yoqni tayyorlash jarayoni

Bo'yoq tayyorlash bir necha bosqichda amalga oshiriladi. Avval polimer bog'lovchi modda kerakli viskozlik darajasiga keltiriladi. Keyin TiO_2 nanozarrachalari asta-sekin qo'shib, bir tekis aralashtiriladi. Aralashtirish jarayonida ultratovushli dispersiya yoki yuqori tezlikli mexanik mikserdan foydalaniladi. Bu nanozarrachalarning bir tekis taqsimlanishini ta'minlaydi. Yakuniy bosqichda stabilizatorlar qo'shib, tayyor aralashma homogen holatga keltiriladi.

5. Fotokatalitik faollikni aniqlash usullari

Fotokatalitik samaradorlik model ifloslantiruvchi moddalar yordamida baholanadi. Odatda metilen ko'ki eritmasi ishlatiladi. Namuna UV nurlanish ostiga qo'yiladi va ma'lum vaqt oralig'ida rang intensivligining o'zgarishi kuzatiladi. Spektrofotometrik o'lchovlar orqali eritma konsentratsiyasining kamayishi aniqlanadi. Bu esa fotokatalitik parchalanish tezligini va samaradorligini hisoblash imkonini beradi.

6. Yorug'likni qaytarish xususiyatlarini o'rganish

Bo'yoqlarning optik xossalari spektrofotometr yordamida o'rganiladi. Turli to'lqin uzunliklarida yorug'likning qaytish darajasi o'lchanadi. Shuningdek, CIELAB rang

tizimi orqali bo'yoqning oqilik darajasi va optik bir xilligi aniqlanadi. Bu ko'rsatkichlar materialning issiqlikni qaytarish samaradorligi bilan bevosita bog'liq hisoblanadi.

7. Mikrostrukturaviy tahlil

Bo'yoq tarkibidagi nanozarrachalarning tuzilishi va taqsimlanishi elektron mikroskopiya usullari orqali o'rganiladi. SEM va TEM tahlillari zarrachalarning o'lchami, shakli va agregatsiya holatini aniqlash imkonini beradi. Rentgen difraksiyasi usuli orqali esa TiO_2 ning kristall fazalari (anataz yoki rutil) aniqlanadi. Bu ma'lumotlar materialning fotokatalitik faolligini tushunishda muhim ahamiyatga ega.

8. Barqarorlik va chidamlilik sinovlari

Tayyor bo'yoqlar turli tashqi omillarga nisbatan sinovdan o'tkaziladi. UV nurlanish, harorat o'zgarishi, namlik va suv ta'siriga chidamlilik tekshiriladi. Shuningdek, mexanik ishqalanish va qoplama yuzasining yemirilish darajasi ham baholanadi. Bu sinovlar materialning uzoq muddatli ishlash samaradorligini aniqlashga yordam beradi.

9. Olingan natijalarni tahlil qilish

Eksperimental natijalar statistik va grafik usullar yordamida tahlil qilinadi. Fotokatalitik jarayon kinetikasi asosida reaksiya tezligi aniqlanadi. Turli tarkibdagi bo'yoqlar o'zaro solishtirilib, eng optimal TiO_2 konsentratsiyasi va eng samarali kompozitsiya aniqlanadi. Natijalar ishonchlilik darajasi va xatoliklar hisobga olingan holda baholanadi.

Muammo va uning tahlili: Hozirgi zamon sanoatlashuvi va urbanizatsiya jarayonlari atrof-muhitga salbiy ta'sirning ortishiga sabab bo'lmoqda. Atmosferaga chiqarilayotgan zararli gazlar, chang zarrachalari hamda turli organik ifloslantiruvchi moddalar ekologik muvozanatni buzib, shaharlar havosining sifatini yomonlashtirmoqda. Bunday sharoitda an'anaviy qurilish va qoplama materiallari ushbu muammolarni hal qilishga yetarli darajada javob bera olmayapti. Ular asosan estetik vazifani bajaradi, biroq ekologik va funksional jihatdan cheklangan imkoniyatlarga ega. Oddiy bo'yoqlar yuzasida chang va ifloslantiruvchi moddalar tez to'planadi, natijada ularni tez-tez yangilash yoki qayta bo'yash zarurati paydo bo'ladi. Bu esa qo'shimcha iqtisodiy xarajatlarni keltirib chiqaradi hamda resurslardan samarasiz foydalanishga olib keladi. Bundan tashqari, quyosh nurlarini qaytarish xususiyati past bo'lgan qoplamalar binolar yuzasining qizishiga sabab bo'lib, issiqlik yuklamasini oshiradi va sovutish tizimlariga bo'lgan energiya sarfini ko'paytiradi. Shu

nuqtayi nazardan, fotokatalitik va yorug'likni qaytaruvchi xossalarga ega yangi avlod materiallariga ehtiyoj ortib bormoqda. TiO_2 nanozarrachalari bu borada eng istiqbolli materiallardan biri hisoblanadi, chunki ular ultrabinafsha nurlar ta'sirida organik ifloslantiruvchilarni parchalay olish va o'z-o'zini tozalash xususiyatiga ega. Biroq ushbu materialni amaliy qo'llashda bir qator muammolar mavjud bo'lib, ular uning to'liq samaradorligini cheklab qo'yadi. Eng asosiy muammolardan biri TiO_2 nanozarrachalarining faolligi asosan ultrabinafsha nurlanish bilan cheklanganligidir, ya'ni quyosh spektrining katta qismini tashkil etuvchi ko'rinadigan yorug'likda ularning samaradorligi pasayadi. Bundan tashqari, nanozarrachalarning o'zaro yopishib qolishi, ya'ni aglomeratsiya jarayoni ularning faol yuzasini kamaytiradi va fotokatalitik faollikni susaytiradi. Bu esa bo'yoq tarkibida notekis taqsimlanish, optik xossalarning buzilishi hamda umumiy samaradorlikning pasayishiga olib keladi. Yana bir muhim masala – bu materialning uzoq muddatli barqarorligi. Tashqi muhit omillari, jumladan UV nurlanish, harorat o'zgarishi va namlik ta'siri natijasida bo'yoqning strukturasi o'zgarishi va uning funksional xossalarning kamayishi kuzatiladi. Shu bilan birga, yorug'likni qaytarish samaradorligi ham ba'zi sharoitlarda yetarli darajada yuqori bo'lmisligi mumkin, bu esa energiya tejamkorlik imkoniyatlarini cheklaydi. Mazkur muammolarni tahlil qilish shuni ko'rsatadiki, TiO_2 nanozarrachalari asosidagi innovatsion bo'yoqlar katta ilmiy va amaliy salohiyatga ega bo'lsa-da, ularning samaradorligini oshirish uchun zarracha yuzasini modifikatsiya qilish, dispersiya texnologiyalarini takomillashtirish, gibrid nanokompozitlar yaratish hamda ko'rinadigan yorug'likda ham faollikni ta'minlovchi usullarni ishlab chiqish zarur. Ushbu yo'nalishlar kelajakda ekologik jihatdan xavfsiz, energiya tejamkor va yuqori samarali qoplama materiallarini yaratish imkonini beradi.

Tadqiqot natijalari va muhokama: Ushbu tadqiqot davomida TiO_2 nanozarrachalari asosida fotokatalitik va yorug'likni qaytaruvchi xossalarga ega innovatsion bo'yoqlar sintez qilindi hamda ularning fizik-kimyoviy, optik va funksional xususiyatlari kompleks ravishda o'rganildi. Olingan natijalar material tarkibi, nanozarrachalar konsentratsiyasi va dispersiya darajasi bo'yoqning umumiy samaradorligiga bevosita ta'sir ko'rsatishini yaqqol namoyon etdi. Dastlabki natijalarga ko'ra, TiO_2 nanozarrachalari bo'yoq tarkibiga kiritilganda uning fotokatalitik faolligi sezilarli darajada oshadi. UV nurlanish ta'sirida model ifloslantiruvchi modda sifatida ishlatilgan organik bo'yoq (masalan, metilen ko'ki)ning parchalanish tezligi nazorat namunaga nisbatan bir necha barobar yuqori bo'ldi. Bu holat TiO_2 yuzasida hosil bo'ladigan elektron–teshik juftlari va ular ishtirokida yuzaga keladigan reaktiv kislorod turlarining ($\bullet\text{OH}$ va O_2^-) yuqori faolligi bilan izohlanadi. Natijalar shuni ko'rsatadiki,

nanozarrachalar miqdori optimal darajaga yetkazilganda fotokatalitik samaradorlik eng yuqori qiymatga erishadi, biroq ortiqcha miqdor zarrachalarning aglomeratsiyasiga olib kelib, aksincha samaradorlikni pasaytirishi mumkin. Optik xossalar bo'yicha o'tkazilgan tahlillar TiO_2 qo'shilishi bo'yoqning yorug'likni qaytarish koeffitsientini sezilarli oshirishini ko'rsatdi. Ayniqsa, ko'rinadigan yorug'lik spektrida yuqori reflektivlik qayd etildi. Bu holat materialning yuqori sindirish ko'rsatkichi va nanozarrachalarning yorug'likni kuchli sochish xususiyati bilan bog'liq. Natijada qoplama yuzasi yuqori darajada oq va yorug'likni qaytaruvchi xususiyatga ega bo'ldi, bu esa issiqlik yutilishini kamaytirish imkonini beradi. Harorat barqarorligi bo'yicha o'tkazilgan kuzatuvlar shuni ko'rsatdiki, TiO_2 asosidagi bo'yoqlar bilan qoplangan yuzalarda quyosh nurlanishi ta'sirida harorat ko'tarilishi sezilarli darajada past bo'ladi. Bu esa ularning "cool coating" tizimlari uchun samarali yechim ekanligini tasdiqlaydi. Shu bilan birga, energiya sarfini kamaytirish va binolarning ichki mikroiklimini barqarorlashtirish imkoniyati mavjudligi aniqlandi. Mikrostrukturaviy tahlillar (SEM va XRD) natijalari TiO_2 nanozarrachalarining bo'yoq matritsasi ichida asosan anataz fazasida tarqalganini va ularning bir qismi rutil fazasiga ham ega ekanligini ko'rsatdi. Anataz faza fotokatalitik faollikning yuqori bo'lishini ta'minlagan bo'lsa, rutil faza materialning umumiy barqarorligini oshirishga xizmat qilgan. Biroq ayrim namunalarda zarrachalarning klasterlashuvi (aglomeratsiya) kuzatilgan bo'lib, bu holat fotokatalitik yuzaning kamayishiga olib kelgan. Muhokama jarayonida aniqlanishicha, bo'yoq tarkibidagi TiO_2 konsentratsiyasi uning funksional xossalarini belgilovchi eng muhim omillardan biridir. Past konsentratsiyada fotokatalitik faollik yetarli darajada bo'lmaydi, juda yuqori konsentratsiyada esa zarrachalar o'zaro to'planib qolib, tizimning bir xilligini buzadi. Shu sababli optimal muvozanatni topish muhim ilmiy va amaliy ahamiyatga ega. Shuningdek, tadqiqot natijalari TiO_2 nanozarrachalarining faolligi faqat ultrabinafsha nurlanish bilan cheklanishi muammosini yana bir bor tasdiqladi. Bu holat ularning real sharoitdagi samaradorligini pasaytirishi mumkin. Shu sababli kelajakda ko'rinadigan yorug'likda ham faollik ko'rsatadigan modifikatsiyalangan TiO_2 tizimlarini ishlab chiqish zarurati mavjudligi qayd etildi. Umuman olganda, olingan natijalar TiO_2 nanozarrachalari asosidagi innovatsion bo'yoqlar yuqori fotokatalitik faollik, kuchli yorug'likni qaytarish xususiyati va ekologik xavfsizlikka ega ekanligini tasdiqladi. Shu bilan birga, ularning samaradorligini yanada oshirish uchun dispersiya barqarorligini yaxshilash, aglomeratsiyani kamaytirish va spektral faollikni kengaytirish bo'yicha qo'shimcha tadqiqotlar olib borish zarurligi aniqlandi.

Xulosa: Ushbu tadqiqot natijalariga ko'ra, TiO_2 nanozarrachalari asosida ishlab chiqilgan innovatsion bo'yoqlar yuqori fotokatalitik faollik, kuchli yorug'likni qaytarish xususiyati hamda ekologik xavfsizlikka ega istiqbolli funksional material ekanligi aniqlandi. O'tkazilgan tahlillar shuni ko'rsatdiki, TiO_2 nanozarrachalari ultrabinafsha nurlanish ta'sirida faol radikallar hosil qilib, organik ifloslantiruvchi moddalarni samarali parchalaydi va yuzaning o'z-o'zini tozalash xususiyatini ta'minlaydi. Shuningdek, bo'yoq tarkibiga TiO_2 nanozarrachalarining kiritilishi uning optik xossalarini sezilarli darajada yaxshilab, yuqori reflektivlik va oq ranglilik darajasini oshiradi. Bu esa binolar yuzasida issiqlik yutilishini kamaytirib, energiya samaradorligini oshirishga xizmat qiladi. Natijalar innovatsion bo'yoqlar "cool coating" tizimlari uchun muhim yechim ekanligini ko'rsatdi. Biroq tadqiqot jarayonida ayrim cheklovlar ham aniqlandi. Xususan, nanozarrachalarning aglomeratsiyaga moyilligi, faollikning asosan UV diapazon bilan cheklanishi hamda uzoq muddatli barqarorlik muammolari mavjudligi qayd etildi. Ushbu muammolarni bartaraf etish uchun nanozarrachalarni sirt modifikatsiyasi, gibrid nanokompozitlar yaratish va ko'rinadigan yorug'likda ham faol bo'lgan tizimlarni ishlab chiqish zarurligi ta'kidlandi. Umuman olganda, TiO_2 nanozarrachalari asosidagi innovatsion bo'yoqlar ekologik toza, energiya tejamkor va ko'p funksiyali material sifatida katta amaliy ahamiyatga ega bo'lib, kelajakda qurilish, sanoat va atrof-muhitni muhofaza qilish sohalarida keng qo'llanilishi mumkin.

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