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BIOSINTEZLANGAN KUMUSH NANOZARRACHALARINING FOTOKATALIZDA QO‘LLANILISHINING AFZALLIKLARI VA KAMCHILIKLARI

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Abstract. This topical review article systematically analyzes the challenges and achievements in the catalytic and photocatalytic degradation of toxic organic dyes in industrial wastewater using silver nanoparticles (AgNPs) obtained via eco-friendly “green synthesis’ methods. Furthermore, current challenges in the field and promising future research directions are outlined.

Keywords: photocatalysis, silver nanoparticles, organic dyes, water treatment, catalytic degradation, biosynthesis, environmental protection.

Annotatsiya. Ushbu mavzuli sharh maqolada ekologik toza “yashil sintez” usulida olingan kumush nanozarrachalari (Ag-NZ) yordamida sanoat oqova suvlari tarkibidagi zaharli organik bo‘yoqlarni katalitik va fotokatalitik degradatsiya qilish muammolari va yutuqlari tizimli tahlil qilingan. Shuningdek, sohadagi mavjud muammolar va kelajakdagi istiqbolli yo‘nalishlar belgilab berilgan.

Kalit so‘zlar: fotokataliz, kumush nanozarrachalari, organik bo‘yoqlar, suv tozalash, katalitik parchalash, biosintez, atrof-muhit muhofazasi.

Аннотация. В данном тематическом обзорном материале систематически анализируются проблемы и достижения в области каталитической и фотокаталитической деградации токсичных органических красителей в промышленных сточных водах с использованием наночастиц серебра (AgNPs), полученных экологически чистым методом «зеленого синтеза». Также обозначены существующие проблемы и перспективные направления будущих исследований в этой области.

Ключевые слова: фотокатализ, наночастицы серебра, органические красители, очистка воды, каталитическая деградация, биосинтез, охрана окружающей среды.

KIRISH.

So‘nggi yillarda sanoatning jadal rivojlanishi va zamonaviy texnologiyalarga bo‘lgan yuqori talab suv resurslarining turli ifloslantiruvchi moddalar, jumladan, zaharli organik bo‘yoqlar va mikroorganizmlar bilan ifloslanishiga olib keldi. Organik bo‘yoqlar to‘qimachilik, oziq-ovqat, qog‘oz, dori-darmon ishlab chiqarish va rangtasvir kabi ko‘plab sohalarda keng

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qo‘llaniladi [1-3]. Biroq, tarkibida ushbu zaharli bo‘yoqlar bo‘lgan sanoat oqova suvlarining dastlabki tozalashdan o‘tkazilmasdan tabiiy suv resurslariga oqizilishi atrof-muhit va ekotizimga jiddiy xavf tug‘diradi. Bunday ifloslanish tuproq xossalarini o‘zgartirib, fauna va floraga tahdid solishi bilan birga, mikroorganizmlarning qirilib ketishiga ham sabab bo‘lishi mumkin. Bundan tashqari, zaharli bo‘yoqlarning ichimlik suvidagi miqdori ruxsat etilgan me’yordan oshib ketishi teri muammolari, ko‘zning yallig‘lanishi, o‘pka kasalliklari, buyrak va jigar shikastlanishi, nafas qisilishi, saraton hamda oshqozon yarasini keltirib chiqarishi mumkin [4;5]. Shuningdek, suv resurslarida bakteriya va zamburug‘lar kabi mikroorganizmlarning mavjudligi vabo, tif, lyamblioz, dizenteriya kabi ko‘plab suv orqali yuquvchi kasalliklarga sabab bo‘ladi [6-8]. Shu bois, ushbu xavfli ifloslantiruvchi moddalarni samarali va tejamkor usullar bilan tozalash orqali suv sifatini yaxshilash dolzarb ilmiy va amaliy muammodir.

Ushbu sharh maqolasini yozishda Scopus, Web of Science va Google Scholar kabi xalqaro nufuzli ilmiy ma‘lumotlar bazalaridan foydalanildi. Qidiruv jarayonida “green synthesis”, “silver nanoparticles”, “photocatalytic degradation”, “organic dyes” kabi asosiy kalit so‘zlardan foydalanildi. Sharhga so‘nggi yillarda yashil sintez usulida olingan, o‘lchami va strukturaviy parametrlari aniq tahlil qilingan hamda geterogen katalizator sifatida qo‘llanilgan kumush nanozarrachalariga oid 70 dan ortiq fundamental ilmiy manbalar saralab olindi va tizimli ravishda tahlil qilindi.

Yashil sintez orqali kumush nanozarrachalarining (AgNZ) sintezi

An’anaviy kimyoviy va fizikaviy jarayonlarning o‘rnini bosuvchi “yashil” sintez tufayli endilikda kumush nanozarrachalarini barqaror hamda ekologik toza usulda ishlab chiqarish imkoniyati mavjud. Ushbu usulda kumush ionlarini nanozarrachalarga aylantirish uchun zamburug‘lar, suvo‘tlar, o‘simliklar va bakteriyalar kabi biologik organizmlardan foydalanilganligi sababli, zararli kimyoviy qaytaruvchilar yoki stabilizatorlar ishlatilmaydi. Ayniqsa, ikkilamchi metabolitlarga boy manba hisoblangan o‘simlik ekstraktlariga alohida afzallik beriladi; chunki ular ham qoplovchi, ham qaytaruvchi agent vazifasini bajaradi.

$$AgNO_3 + H_2O\ (DI) \rightarrow\ Ag+\ (suvli) + NO_3\ -\ (suvli)$$

$$Ag+\ (suvli) + NO_3-\ (suvli) + \text{o‘simlik ekstrakti (suv)} \rightarrow Ag^0\ (NZ)\ (suvli\ muhit) + NO^-_3$$

Masalan, *Azadirachta indica* va *Eucalyptus globulus* o‘simliklari ekstraktlaridan foydalanish natijasida o‘lchami va shakli nazorat qilingan nanozarrachalar sintez qilingan [9].

Bundan tashqari, *Syzygium jambos* [10], *Coriandrum sativum* [11], *Prunus yedoensis* [12], *Bunium persicum* [13], *Vigna radiata* [14], *Adenium obesum* [15],

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Microsorum pteropus [16] va *Lantana camara* [17] kabi o‘simliklarning barchasi istiqbolli natijalarni ko‘rsatgan. Shuningdek, *Aspergillus niger* va boshqa zamburug‘lar ham kumush nanozarrachalari sintezida qo‘llanilgan bo‘lib, bu jarayon zamburug‘ oqsillarining barqarorlashtirish (himoya) yo‘lidagi funksiyasini ko‘rsatadi [18, 19]. Qo‘shimcha ravishda, suvo‘tlar ishtirokidagi ishlab chiqarish ham yaxshi istiqbolga ega; mo‘tadil sharoitlarda *Chlorella vulgaris* (suvo‘tsimon) kumush nanozarrachalarini hosil qilishga yordam bergan[10, 11].

Ushbu xususiyatlar “yashil” sintezni ekologik va tibbiy maqsadlar uchun jozibador tanlovga aylantiradi. “Yashil” usullar yordamida kumush nanozarrachalarini tayyorlash bir qator omillarga, jumladan, kumush ionlarining miqdori, pH muhit, biologik materialning turi, harorat va reaksiya vaqtiga bog‘liq. Masalan, foydalanilgan o‘simlik ekstraktining turi hosil bo‘ladigan nanozarrachalarning o‘lchami va tuzilishiga jiddiy ta’sir ko‘rsatishi mumkin. Singx va Dutta hammuallifligidagi tadqiqotlarga ko‘ra, kashnich (petrushka) barglarining suvli ekstrakti o‘rtacha o‘lchami 20–30 nm oralig‘ida bo‘lgan sferik (sharsimon) shakldagi kumush nanozarrachalarini hosil qilgan [10; 20]. Reaksiya parametrlari hisoblangan harorat va pH muhit ham juda muhim ahamiyatga egaligi qayd etilgan. Neytral pH sharoitida reaksiya haroratining ko‘tarilishi kichikroq o‘lchamdagi nanozarrachalar hosil bo‘lishiga yordam berishi aniqlangan [21]. O‘simlik ekstraktlari tarkibidagi alkaloidlar, flavonoidlar va terpenoidlar kabi o‘ziga xos fitokimyoviy moddalarning mavjudligi qaytarilish va barqarorlashish (stabilizatsiya) jarayonlarini yanada osonlashtiradi. Masalan, *Camellia sinensis* (yashil choy) ekstraktidan foydalanilganda [22], flavonoidlar kumush nanozarrachalari ishlab chiqarishda muhim qaytaruvchi agentlar ekanligi aniqlandi [23]. Sunday qilib, “yashil” sintez yondashuvi nanozarrachalarning biologik faolligini oshirish bilan bir vaqtda, ularning atrof-muhitga bo‘lgan salbiy ta’sirini ham kamaytiradi.

Katalitik qaytarilishda nanozarrachalarning ahamiyati

Katalitik qaytarilish usuli qo‘llash osonligi, tejamkorligi, tozaligi hamda ifloslangan suvni organik bo‘yoqlardan tez fursatda tozalash qobiliyati tufayli katta qiziqish uyg‘otdi. Ushbu usulda zaharli organik bo‘yoqlar ekologik toza, xavfsiz va iqtisodiy jihatdan arzon bo‘lgan qaytaruvchi agent — odatda natriy borgidrid ($NaBH_4$) yordamida hamda organik bo‘yoqning qaytarilishini osonlashtiradigan, qayta foydalanish mumkin bo‘lgan qattiq katalizator ishtirokida kamroq zaharli yoki zaharli bo‘lmagan mahsulotlarga aylantiriladi. Katalizatorning asosiy vazifasi elektronlarni donorlardan akseptorlarga o‘tkazishdan iborat bo‘lib, bu jarayon elektron uzatilishiga yordam beruvchi “elektron relesi” vazifasini bajaradigan oraliq oksidlanish-qaytarilish potensialini

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yuzaga keltiradi [8, 24, 25]. Ushbu jarayon katalizatorsiz kechganda termodinamik jihatdan qulay, ammo kinetik jihatdan noqulay bo‘lganligi sababli, o‘zining noyob fizik-kimyoviy xossalari tufayli turli xil nanomateriallardan katalizator sifatida foydalaniladi [25–30]. Bunday katalizatorlar sirasiga kumush nanozarrachalari (Ag-NZ) [30, 31], oltin nanozarrachalari [32, 33], temir oksidi nanozarrachalari [34], grafen oksidi [35, 36] va palladiy nanozarrachalari [37, 38] kiradi. Nanomateriallarni sintez qilishda “yuqoridan-pastga” (top-down) va “pastdan-yuqoriga” (bottom-up) usullari qo‘llaniladi.

Shuningdek, sintez metodologiyalarini biologik, fizik, kimyoviy, fotokimyoviy va elektrokimyoviy usullarga ajratish mumkin [39-42]. Garchi ushbu usullarning aksariyati toza va aniq shakllangan nanomateriallarni bersa-da, ularning ko‘pchiligi qimmat, ko‘p vaqt talab qiladigan va zaharli kimyoviy moddalardan foydalanish zarurati tufayli ekologik jihatdan zararli hisoblanadi. Shu sababli, biologik usul ekologik toza, tejamkor va sanoat miqyosida qo‘llashga mos deb hisoblanadi [43-45].

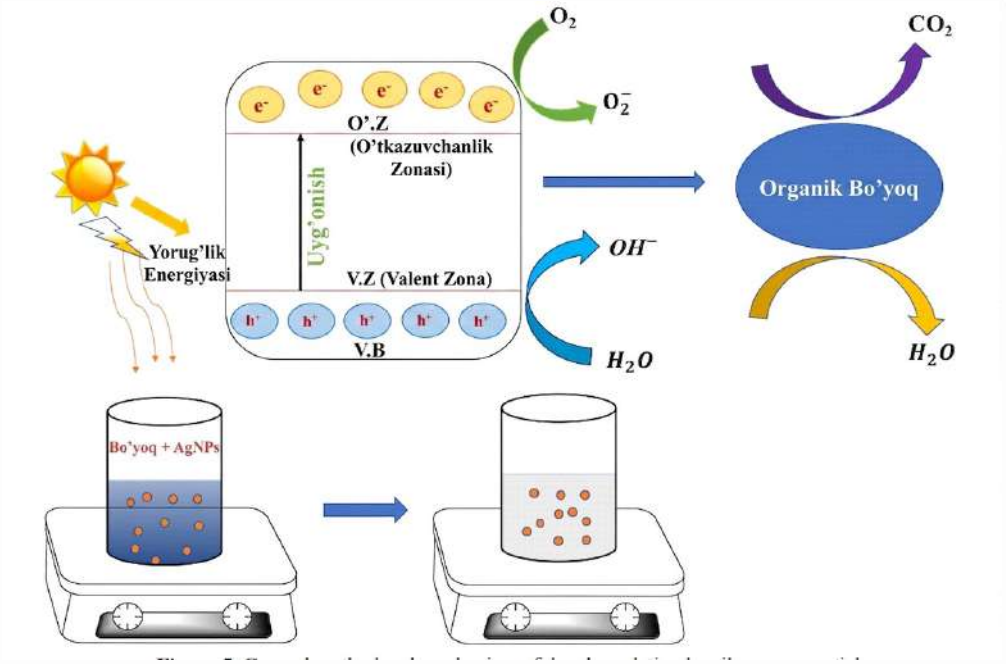
Kumush nanozarrachalari (Ag-NZ) ning fotokatalitik xususiyatlari

Kumush nanozarrachalari (Ag-NZ) 1 dan 100 nanometrgacha bo‘lgan o‘lchamlarga ega nanotuzilmali materiallar bo‘lib, ular xromatografiya, dori vositalariga chidamlilik kabi turli sohalarda hamda mikroblarga qarshi kurash, mikro-DNK va leykoz-DNKni aniqlash kabi biologik yo‘nalishlarda keng foydalaniladi [46–51]. Kimyoda esa organik sintezda yoki suvni organik ifloslantiruvchi moddalardan tozalashda geterogen katalizator sifatida alohida ahamiyatga ega. Biologik usul orqali Ag-NZ sintezi arzonligi va ekologik tozaligi tufayli eng afzal usul hisoblanadi. Turli tadqiqot guruhlari *Nervalia zeylanica*, *Terminalia arjuna*, *Artemisia oliveriana* [52], *Solanum indicum linn* [53], *Persicaria odorata, Caralluma acutangula* [54], va *Citrus macroptera* [55] kabi o‘simliklarning ekstraktlaridan foydalangan holda biosintez yondashuvi orqali Ag-NZ olganlar. Xulosa o‘rnidan olingan Ag-NZ ning o‘lchamlari va xossalari o‘simlik ekstraktlaridagi fitokimyoviy moddalarning tabiati sababli turlicha bo‘lishi urg‘ulangan.

Bugungi ilmiy hamjamiyatda, biosintez qilingan Ag-NZ yordamida quyosh nuri ostida ko‘plab bo‘yoqlar moddalarini fotokatalitik parchalashga oid tadqiqotlar diqqatga sazavordir. Quyosh nurlanishiga ta‘sir qilish (nurlanish vaqti) Ag-NZ ning fotokatalitik parchalanish faolligida asosiy rolni o‘ynaydi. Jarayonda, ma‘lum bir reaksiya vaqtidan keyin rangning to‘q ko‘kdan och ko‘kka o‘zgarishi yoki butunlay rangsizlanishi kuzatiladi. Nurlanish vaqti ortishi bilan bo‘yoqning yutilish intensivligi kamayadi va buni ultrabinafsha va ko‘rinadigan sohada optik zichlikni o‘lchash orqali baholash mumkin. Yutilish intensivligining pasayishi bo‘yoqning qaytarilayotganini, ya‘ni Ag-NZ ishtirokida bo‘yoq

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parchalanayotganini anglatadi. Bundan tashqari, parchalanish tezligi zarrachalarning o‘lchami, strukturasi, morfologiyasi va Ag-NZ konsentratsiyasi kabi turli parametrlarga ham bog‘liq. Bular orasida zarracha o‘lchami bo‘yoq parchalanishidagi eng muhim parametrdir. Zarracha o‘lchami qanchalik kichik bo‘lsa, hajmga nisbatan sirt maydoni shunchalik katta bo‘ladi va reagentlarning sirtga adsorbsiyalanishi kuchayadi; bu esa o‘z navbatida reaksiya tezligini oshiradi. Adabiyotlarda keltirilishicha, Ag-NZ bo‘yoqni parchalash jarayonida elektronlarni o‘tkazib beruvchi (mediator) vazifasini bajaradi. Shuningdek, fotokatalitik faollik Ag-NZ ning sirt plazmon rezonansi ta‘siri hisobiga sodir bo‘lishi ham ta‘kidlangan. Ya‘ni, bo‘yoqning parchalanish tezligi Ag-NZ ning fotonlar (yorug‘lik) yordamida ta‘sirlanishi orqali tezlashadi (1-rasm)



1-rasm. Kumush nanozarrachalari tomonidan buyoqlarning parchalanishi jarayonining umumiy mexanizmi

“Yashil sintez” usulida olingan kumush nanozarrachalarining turli xil bo‘yoqlarga, jumladan, Metilen ko‘ki (MB) [56–58], Rodamin B (RhB) [58, 59–61], Nitrofenol [58, 62–63], Kongo qizili (Congo Red), Kaliy permanganat ($KMnO_4$) [60], Olti valentli xrom [24], Kristal binafsha (Crystal Violet) [59], Coomassie och ko‘ki (Coomassie Brilliant Blue) [59], to‘qimachilik sanoati bo‘yoqlari [61, 64], metil zarg‘aldog‘i (methyl orange) [59, 65] va sariq G (Orange G) [66] larga ko‘rsatadigan fotokatalitik faolligi bo‘yicha ko‘plab ilmiy ishlar nashr etilgan. Bundan tashqari, ”yashil sintez” orqali olingan kumush nanozarrachalari parasetamol kabi faol farmatsevtika ingredientlarni parchalashda ham qo‘llaniladi [67]. Shuningdek, saraton kasalligini keltirib chiqaruvchi organik erituvchilar — benzol, toluol va fenol ham ushbu nanozarrachalar yordamida degradatsiyaga uchratilishi mumkin [68].

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Adabiyotlardan olingan qiyosiy ma‘lumotlar shuni ko‘rsatadiki, J. Saha va boshqalar [56] o‘rtacha o‘lchami 17 nm bo‘lgan 3,0 ml kumush nanozarrachalari ishtirokida metilen ko‘ki bo‘yog‘ining 10 daqiqa ichida 100% parchalanishini kuzatgan. R. Banu va boshqalar [58] MB bo‘yog‘ini parchalash uchun Ag-NZ ning optimal miqdori o‘rtacha o‘lchami 15 nm bo‘lgan holatda taxminan 100 µL ekanligini, shuningdek, Rodamin B va 4-Nitrofenolning ham parchalanishini aniqlashgan. F. Baghbani-Arani va boshqalar [69] ultrabinafsha (UV) nurlanish ostida 60 daqiqalik ta‘sir qilishdan so‘ng, Coomassie och ko‘ki G-250 bo‘yog‘ining 100% samaradorlik bilan parchalanishini tajribada tasdiqlagan.

1-jadvalda bir nechta bo‘yoqlarning parchalanishi bo‘yicha olib borilgan qiyosiy tadqiqotlar natijalari ko‘rsatilgan. Ushbu jadval yashil sintez usulida olingan kumush nanozarrachalari (AgNZ) yordamida turli xil organik bo‘yoqlarning parchalanish samaradorligi bo‘yicha olib borilgan qiyosiy tadqiqotlar natijalarini umumlashtiradi.[70]. Ma‘lumotlar ilmiy adabiyotlardan to‘plangan bo‘lib, AgNZ sintezida ishlatilgan substrat, bo‘yoq turi, parchalanish samaradorligi, vaqt va yorug‘lik manbai/qaytaruvchi vosita kabi asosiy parametrlarni o‘z ichiga oladi.

1-jadval.

Nanozarrachalari yordamida turli xil organik bo‘yoqlarning parchalanish samaradorligi

AgNZ sintezida ishlatilgan substrat	**Bo‘yoq turi**	**Parchalanish samaradorligi (%)**	**Vaqt**	**Yorug‘lik manbai/Qaytaruvchi vosita**
Sterculia acuminata meva ekstrakti	Metilen ko‘ki (MB)	Tez parchalanish	Noma‘lum	Noma‘lum
Mussaenda glabrata barg ekstrakti	Metilen ko‘ki (MB), Metil zarg‘aldog‘i (MO)	Kuzatilgan	Noma‘lum	Noma‘lum
Cassia Alata barg ekstrakti	Rodamin, Metil zarg‘aldog‘i, Metilen ko‘ki	Kuzatilgan	Noma‘lum	Noma‘lum

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Ag-ZnO nanokompozi ti	Metilen ko‘ki (MB), Rodamin B, Metil zarg‘aldog‘ i (MO)	MB: 98.7%, RhB: 99.4%, MO: 92.9%	Noma‘lu m	Noma‘lum
Biogen AgNZ (umumiy)	Metilen ko‘ki (MB)	~95%	72 soat	Noma‘lum
Ageratum conyzoides	Metilen ko‘ki (MB)	100%	105 min	Quyosh nuri
Albizia procera	Metilen ko‘ki (MB)	51.5%	70 min	UB
Alpinia officinarum	Metilen ko‘ki (MB)	80%	120 min	Ko‘rinadigan nur
Antidesma acidum	Metilen ko‘ki (MB)	81%	18 min	$NaBH_4$
Biophytum sensitivum	Metilen ko‘ki (MB)	90.66%	9 min	$NaBH_4$
Amaranthus gangeticus	Kongo qizili (CR)	100%	15 min	UV + $NaBH_4$
Anacardium occidentale	Kongo qizili (CR)	100%	30 min	$NaBH_4$
Cordia dichotoma	Kongo qizili (CR)	100%	20 min	Quyosh nuri
Cuphea procumbens	Kongo qizili (CR)	86.6%	5 min	Quyosh nuri
Alpinia nigra	Metil zarg‘aldog‘ i (MO)	83.4%	90 min	Quyosh nuri
Anacardium occidentale	Metil zarg‘aldog‘ i (MO)	100%	20 min	$NaBH_4$
Dodonaea viscosa	Metil zarg‘aldog‘ i (MO)	96.2%	4 min	$NaBH_4$
Eucalyptus globulus	Metil zarg‘aldog‘ i (MO)	90%	10 min	$NaBH_4$

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Alpinia nigra	Metil zarg‘aldog‘i (MO)	83.4%	90 min	Quyosh nuri

Yana boshqa tadqiqotda keltirilishicha, evkalipt globulus barg ekstraktidan sintezlangan biogen kumush nanozarralari (Ag NZ) zaharli Kongo Qizil bo‘yog‘ini parchalashda samarali bo‘lib, 8 daqiqa ichida ko‘rinadigan yorug‘lik ostida 98,9% gacha degradatsiyaga erishish haqida xulosa qilingan. Fotokatalitik degradatsiya jarayoni pseudo-birinchi tartibli kinetik modelga amal qilishi bu reaksiya uchun yuqori tezlik doimiyligini ko‘rsatishi qayd qilingan [71]. Bo‘yoq konsentratsiyasi, katalizator dozasi va yorug‘lik ta‘siri kabi parametrlarni optimallashtirish AgNZ larning degradatsiya samaradorligiga sezilarli darajada ta‘sir qiladi. Bu esa, yashil sintezlangan Ag NZ-larining atrof-muhitni qayta tiklash, xususan oqava suvlarni tozalashda salohiyatini ta‘kidlaydi va an‘anaviy usullarga barqaror muqobillikni taklif qiladi.

Shunday qilib adabiyotlar tahlilidan ma‘lumki, Kumush nanozarrachalari o‘lchamining turli xil rangli moddalarni parchalashda muhim ahamiyatga ega ekanligi takidlandii. Nanozarracha o‘lchami qanchalik kichik bo‘lsa, u shunchalik tez va samarali parchalanadi. Bundan tashqari, kumush nanozarrchalarining konsentratsiyasi ham jarayon unumdorligi va bo‘yoq parchalanishiga ta‘sir qiladi: konsentratsiya qanchalik yuqori bo‘lsa, bo‘yoqning parchalanish darajasi ham shunchalik yuqori bo‘ladi.

Mavjud muammolar va kelajakdagi istiqbollar.

Garchi yashil sintez usulida olingan Ag-NZ yuqori fotokatalitik va katalitik samaradorlik ko‘rsatsa-da, sanoat miqyosida qo‘llashda quyidagi jiddiy muammolar mavjud:

✓ vaqt o‘tishi bilan yoki eritma muhiti o‘zgarganda nanozarrachalarning o‘zaro yopishib (agglomeratsiya), faol sirt maydonini yo‘qotishi.

✓ nanoo‘lchamli kukunlarni tozalangan suv tarkibidan ultra-sentrifugalashsiz qayta ajratib olishning qiyinligi. Bu esa iqtisodiy jihatdan xarajatlarni oshiradi.

✓ turli hududlarda va fasllarda yig‘ilgan o‘simlik ekstraktlari tarkibidagi polifenollar miqdori turlicha bo‘lganligi sababli, sintez qilinayotgan nanozarrachalarning o‘lchamlarini standartlashtirish qiyin kechadi.

Ushbu muammolarni hal qilish va sohani rivojlantirish uchun kelajakda quyidagi yo‘nalishlarga e‘tibor qaratish lozim:

➢ Ag-NZ larni kukun holida emas, balki magnitli zarrachalar (Fe_2O_3), rux oksidi (ZnO) yoki grafen kabi substrat-matritsalarga o‘tqazish Ag-ZnO kabi kompozit nanomateriallar olish, ularni suvdan magnit yordamida oson ajratib olish imkonini beradi.

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➢ Laboratoriya sharoitidagi (ml) hajmlarni yirik sanoat reaktorlari darajasiga ko‘tarish texnologiyasini ishlab chiqish.

Adabiyotlar tahlili shuni ko‘rsatadiki, yashil sintez kumush nanozarrachalari ekologik xavfsiz va yuqori samarali geterogen katalizatorlar hisoblanadi. Ularning o‘lchami qanchalik kichik (15-20 nm) va konsentratsiyasi muvozanatlashgan bo‘lsa, organik ekotoksikantlarni parchalash tezligi shunchalik yuqori bo‘ladi. Bundan tashqari, kumush nanozarrchalarining konsentratsiyasi ham jarayon unumdorligi va bo‘yoq parchalanishiga ta‘sir qiladi: konsentratsiya qanchalik yuqori bo‘lsa, bo‘yoqning parchalanish darajasi ham shunchalik yuqori bo‘ladi. Biosintez qilingan Ag-NZ ning fotokatalitik faolligi suvni organik ifloslantiruvchi moddalardan tozalashda yuqori samaradorlikka ega bo‘lsada ba‘zi kamchiliklardan holi emas. Shuning uchun, kelajakda ularni barqaror kompozitlar shakliga keltirish orqali global oqova suv muammolariga yashil texnologiyalar yordamida yechim taklif qilish mumkin.

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