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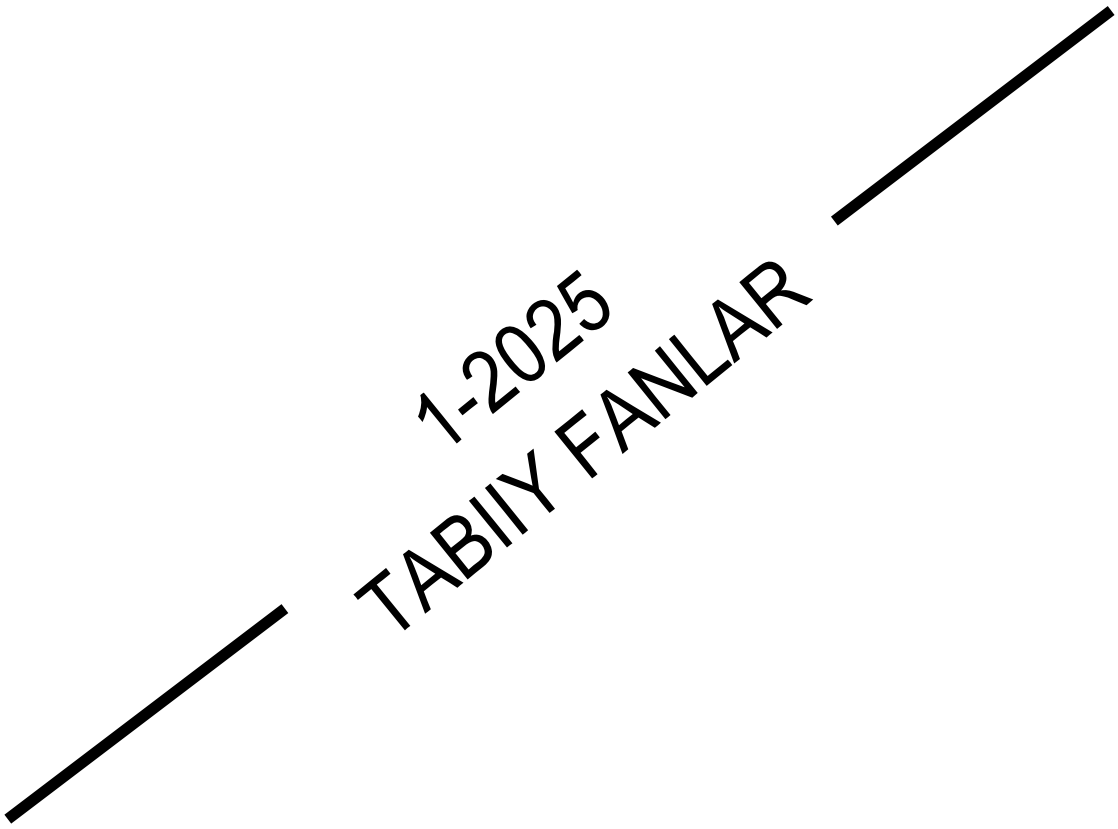

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TEMIR ASOSIDA METALL−ORGANIK ADSORBENTLAR OLISHNING SAMARALI USULLARI (ADABIYOTLAR TAXLILI)

ЭФФЕКТИВНЫЕ МЕТОДЫ ПОЛУЧЕНИЯ МЕТАЛЛ-ОРГАНИЧЕСКИХ АДСОРБЕНТОВ НА ОСНОВЕ ЖЕЛЕЗА (ЛИТЕРАТУРЫНЫЙ ОБЗОР)

EFFECTIVE METHODS FOR PRODUCING METAL-ORGANIC ADSORBENTS BASED ON IRON (LITERATURE REVIEW)

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Annotatsiya

Ekologik muammo insoniyat oldida turgan hozirgi kundagi asosiy muammodir. Turli xildagi ishlab chiqarishlar sanoatining jadal rivojlanishi bilan organik va noorganik ifloslantiruvchi moddalarni o‘z ichiga olgan zaharli oqava suvlarning ko‘p miqdorda doimiy ravishda hosil bo‘lishi ham odamlarga, ham atrof-muhitga jiddiy zarar etkazmoqda. Shu sababli, oqava suvlarni tozalashning samarali usullarini tadqiq qilish bugungi kunga kelib dunyo olimlarining oldidagi dolzarb vazifalardan biriga aylanmoqda. O‘zbekiston Respublikasi prezidenti Shavkat Mirziyoyev 2025-yilni “Atrof-muhitni asrash va yashil iqtisodiyot yili” deb e’lon qilishi ham bejiz emas.

Ushbu maqolada, keltirilgan faktlarga tayanib metall-organik panjaralar sintezi bo‘yicha so‘nggi yillardagi manbalarning taxlili yoritilgan va 3 turdagi (Fe-BTC- iron- 1,3,5-benzenetricarboxylate- framework, MOP-235- Iron terephthalate metal-organic framework, CHCFe -coconut husk-clay-ferrate composite) temir va organik moddalar asosida adsorbentlarni sintez qilish jarayonlari o‘rganilib bayon qilingan. Adsorbentlarni olish jarayonining xom ashyosi, parametrlari, bosqichlari haqida ma’lumot berilgan. Ushbu tadqiqotlar, kelajakda ekologik toza va samarali adsorbentlar ishlab chiqarish imkoniyatlarini kengaytiradi va atrof-muhit muhofazasi sohasida yangi yutuqlarga olib kelishi kutilmoqda.

Аннотация

На сегодняшний день экологическая проблема является одной из основных проблем, стоящих перед человечеством. Быстрое развитие различных производств приводит к постоянному образованию значительных объемов токсичных сточных вод, содержащих органические и неорганические загрязняющие вещества, что наносит серьезный вред как людям, так и окружающей среде. Поэтому исследование эффективных методов очистки сточных вод становится одной из актуальных задач для ученых всего мира. Не случайно Президент Республики Узбекистан Шавкат Мирзиёев объявил 2025 год "Годом охраны окружающей среды и зеленой экономики".

В данной статье на основе приведенных фактов представлен анализ литературы последних лет по синтезу металл-органических каркасов и процессам синтеза трех типов адсорбентов на основе железа и органических веществ (Fe-BTC – железо-1,3,5-бензолтрикарбоксилатный каркас, MOP-235 – железо-терафталатный металл-органический каркас, CHCFe – кокосовая шелуха-глина-железистый композит). Приведены сведения о сырье, параметрах и стадиях процесса производства адсорбентов. Ожидается, что эти исследования в будущем расширят возможности производства экологически чистых и эффективных адсорбентов, что будет способствовать новым достижениям в области охраны окружающей среды.

Abstract

Today, environmental issues are among the most pressing challenges facing humanity. The rapid expansion of various industries has led to the continuous generation of large volumes of toxic wastewater containing organic and inorganic pollutants, causing significant harm to both human health and the environment. As a result, the study of

effective wastewater treatment methods has become a priority for scientists worldwide. It is no coincidence that the President of the Republic of Uzbekistan, Shavkat Mirziyoyev, declared 2025 as the "Year of Environmental Protection and Green Economy."

This article, based on the presented facts, provides a literature review of recent research on the synthesis of metal-organic frameworks and the production processes of three types of iron-based adsorbents: Fe-BTC (iron-1,3,5-benzenetricarboxylate framework), MOP-235 (iron terephthalate metal-organic framework), and CHCFe (coconut husk-clay-ferrate composite). Information is provided on raw materials, process parameters, and adsorption production stages. These studies are expected to expand the possibilities for developing eco-friendly and efficient adsorbents, contributing to further advancements in environmental protection.

Kalit so'zlar: *metal- organik panjara, adsorbsiya, faza, aralashma, maydalash, quritish*
Ключевые слова: *металл-органический каркас, адсорбция, фаза, смесь, измельчение, сушка*
Key words: *metal-organic framework, adsorption, phase, mixture, grinding, drying*

KIRISH

Hozirgi kunda Respublikamiz yirik sanoat va agrar mintaqa sifatida tanilgan. Kelajakda mashinasozlik, energetika, kimyo, oziq-ovqat sanoati va transport sohalarini yanada rivojlantirish rejalashtirilmoqda. Bunday ishlab chiqarish kuchlarining o'sishi Respublikadagi ijtimoiy-ekologik tizimlarga ma'lum darajada salbiy ta'sir ko'rsatadi. Shu sababli ayni vaqtda Respublikada mavjud ekologik va tabiatni muhofaza qilish muammolari talaygina [1].

Shubhasiz, turli xil suv ifloslantiruvchi moddalarni samarali ushlay oladigan yangi adsorbent materiallarni o'rganish va ishlab chiqish zarur. Ushbu jabhada ko'plab dunyo olimlarida samarali adsorbent sifatida metal-organik panjaralariga qiziqish uyg'onmoqda.

ADABIYOTLAR TAHLILI VA METODOLOGIYA

Metall-organik panjaralar (MOP) g'ovakli gibrid(organik va noorganik), metal ioni va organik ligandlar bilan bog'langan 3D kristall moddadir.[2]

O'ziga xos sirt maydonining kattaligi, yuqori g'ovakliligi va molekulyar darajada boshqarilishi tufayli MOPlar adsorbsiya[3], kataliz[4], gazni adsorbsiyalash va saqlash [5], dori vositalarini yetkazib berish [6], ifloslantiruvchi moddalarni ajratish [7] kabi jabhalarda ulkan potentsial namoyish etgan. [8] manba mualiflari tomonidan xona haroratidagi suvli eritmada, 1 ta reaktordan foydalanilgan holda temir asosidagi Fe-BTC metal organik panjarasini olishning sodda usuli taklif qilingan.

Aytilganidek tadqiqot suyuq fazali sistemada amalga oshirilgan bo'lib, avval metal tuzi eritmasi, ishqor eritmasi va stabilizatorlarni aralashtirib oraliq mahsulot hosil qilingan. So'ng oraliq mahsulotni MOP ga aylantirish uchun organik liganda eritmasi qo'shilgan [9].

Sintez jarayoni quyidagicha olib borilgan: avval 2,386 g $FeCl_2 \cdot 4H2O$ (12 mmol) 200 ml sig'imli stakanda 25 ml deionlashtirilgan suv bilan eritilgan. So'ng NaOH (2 mol/l) va Na_2SO4 (0,4 mol/l) larning eritmalari 10 ml dan tayyorlangan. Hosil bo'lgan eritmalarni yuqorida tayyorlangan 3 valentli temir tuzi eritmasiga qo'shilib va ma'lum bir vaqt tez-tez aralashtirilgan. So'ng 80 ml H3BTC trimezin kislotasi asta tomchilatib qo'shilgan va 12 soat mobaynida to'q yashil rangdan sariqqa, hamda jarayon oxirida och jigarrangga o'zgargungacha to'xtovsiz aralashtirilib turilgan. Va nihoyat, mahsulot spirt va distillangan suv bilan 3 marta yuvilib 80^0 haroratda quritilgan.

MOP hosil qilishning tayyorlov jarayoni quyidagi 2 bosqichni o'z ichiga olgan:

1. SO_4^{-2}–interkalirlangan temir gidroksidi kislorodsiz muhitda hosil bo'lgan.
2. Konversiya jarayonini ishga tushirish uchun H3BTCning spirtli eritmasi suspenziyaga qo'shilgan. Reaksiyada tanaffuslar bo'lgan hamda 1 ta reaktorda bir necha daqiqalarda yakunlangan.

Shuni ta'kidlab o'tish joizki, ushbu metod yordamida sintez qilingan mahsulotning chiqish unumi, qo'shilgan metall miqdoriga nisbatan hisoblanganda 53,3% ni tashkil qilgan. Bu metodning ustunligi tayyorlanish sharoitini soddaligi bo'libgina qolmasdan, yuqori unumdorlik hamda jarayonda zararli moddalarni ishlatilmaganligi va rangli chiqindilarni hosil bo'lmaganligidadir.

Yaqin o'tmishdan beri MOP ifloslantiruvchi moddalardan adsorbsiya qilish bilan tozalashda qo'llanilib kelinmoqda. Misol uchun [10] manbaga ko'ra 2010-yilda ilk bor MIL-101 va MIL-53 namunalari suvni metiloranjdan adsorbsion tozalashda qo'llanilgan deb yoritilgan.

Shu vaqtdan boshlab sirkoniy [11-14], temir [15,16], alyuminiy [17], zinc [18], nikel [19-21], xrom [22,23], kobalt [24] va mis [25,26] kabi turli xil metallardann siztez qilingan MOP lar bilan bo‘yoqlarni adsorbsiya qilishga ko‘plab urinishlar o‘tkazilgan.

Adsorbent tayyorlash uchun avvalo 205 mg (1,23 mmol) 1,4-H2BDC 1,4-benzoldikarbon kislotasi 60 ml DMF dimetilformamid bilan eritma shaffof bo‘lgunga qadar aralashtirilgan. So‘ng eritmaga 200 mg FeCl3·6H2O (0,738 mmol) qo‘shib 5 daqiqa davomida aralashtirilgan. Shundan so‘ng 30ml shaffof reaksion eritmani hamda 30 ml etanolni Teflon qoplamali avtoklavga qo‘yib 24 soat mobaynida 80^0 haroratda qizdirilgan. MOF-235 ning to‘q sariq kristallarini sentrifugalab ajratib olingan va dimetilformamid-etanol aralashmasi bilan 3 marta yuvilib vakuumda quritilgan.

Shunday qilib, Fe asosida MOF-235 sodda solvotermik metod orqali muvaffaqiyatli sintez qilingan [27].

Ushbu maqolada [28] alternativ, arzon, samarali adsorbent olish uchun gil tuproq, kakos qobig‘i va Fe tuzlaridan kopmozit material olish tadqiq qilingan.

Magnitli bog‘lovchi deb nomlangan temir tuzi adsorbsion xossalarni yaxshilash, g‘ovaklilikni oshirish hamda bog‘larni mustahkamlash maqsadida komposit tarkibiga qo‘shilgan

Gil tuproqning ajoyib adsorbsion xususiyatlari kakos yong‘og‘i qobig‘ida (biomasa) mavjud bo‘lgan funktsional guruhlari bilan birlashib, samaradorligi yuqori bo‘lgan adsorbent hosil bo‘lishiga olib keladi.

Kompozitni sintez qilishda xom ashyoning arzonligi va mavjudligi (gil va kakos yong‘og‘i qobig‘i), ekologik toza kimyoviy moddalardan foydalanganligi, energiya sarfining yo‘qligi va sintezning oddiyligi hisobga olingan.

CHCFe ni tayyorlash jarayoni quyidagicha borgan. Chiqindilarni tozalash uchun samarali adsorbent materialni topish uchun kokos qobig‘i (qishloq xo‘jaligining chiqindisi), giltuproq (ko‘p va arzon), magnit zarralardan (atrof-muhitni ifloslantiruvchi moddalarni ushlab qolish qobiliyatiga ega) [29] va CaO (barcha komponentlarning to‘g‘ri aralashishini ta'minlash vazifasiga ega) [30] dan CHCFe kompoziti tayyorlangan.

Kakos qobig‘i avval suv bilan, so‘ng distillangan suv bilan yuvilib 7 kun mobaynida namlikni yo‘qotish uchun quyosh nurida quritilgan. Mayin zarralarni olish maqsadida maydalanib 2mm o‘lchamga ega bo‘lgan tirqishli elakdan o‘tkazilgan.

Gil tuproq 5 kun mobaynida quyosh nurida, 24 soat davomida 90^0C haroratda pechda quritilgandan so‘ng maydalanib 2mm o‘lchamga ega bo‘lgan tirqishli elakdan o‘tkazilgan.

100 gr KQK (kakos qobig‘i kukuni), 100 gr GT (gil tuproq) va 300 ml distillangan suv yaxshilab aralashtirilgan va bu “A” aralashma deb nomlangan.

40gr dan temir sulfat tuzlari ($Fe_2(SO_4)_3 \cdot H_2O$ va $FeSO_4 \cdot 7H_2O$) tortilib alohida idishlarda 50ml suv bilan eritilgan. Hamda ikkala eritma aralashtirilib “B” aralashma deb nomlangan.

CaO, $Ca(OH)_2$ и $CaCO_3$ larning aralashmasidan 20 gr tortib 50 ml suv bilan eritilganva bu “C” aralashma deb nomlangan.

70^0C haroratda “A, B, C” aralashmalar magnitli aralashtirgichda 1 soat mobaynida aralashtirilgan. Hosil qilingan aralashmaning muhitini, ph= 10, ushlab turish uchun aralashtirish jarayonida qurilmaga bir necha tomchi 10 mol/l li NaOH qo‘shilgan. Muvozanatga keltirish maqsadida olingan maxsulot 24 soat mobaynida tindirilgan. So‘ng shaffof eritmadan cho‘kma, ya’ni adsorbentni ajratib, distillangan suv bilan yuvib, 48 soat 80 C haroratda quritilgan. 106 mkm o‘lchamli elakdan o‘tkazilib germetik idishda eksikatorning ichida saqlangan.

NATIJA VA MUHOKAMA

Tayyorlangan Fe-BTC o‘zaro elektron ta'sirlar hisobiga turli anionli rang beruvchilar: metil oranj (31,82 mg/g) va konqo-qizil (146,1 mg/g), shuningdek, kationli rang beruvchilar: metilen ko‘k (290 mg/g) va rodamin B (57 mg/g) va og‘ir metall ionlari: Pb^{2+} (18 mg/g) uchun yuqori adsorbsion unumiga ega ekanligini ko‘rsatgan.

Temir asosidagi metall-organik panjara (MOF-235) oddiy solvotermal usul orqali muvaffaqiyatli sintez qilingan va konqo-qizil va meti oranjni suvli eritmalardan olib tashlash uchun adsorbent sifatida ishlatilgan. MOF-235 va rang beruvchi modda orasidagi gidrofobik ta’sir hisobiga quyidagi natijalar olingan. Langmuir izotermasiga bo‘yicha maksimal adsorbsion qobiliyati kongo - qizil uchun 1250 mg/g va metal oranj uchun 250 mg/g ga yetgan.

Gil tuproq, kokos qobig‘i va noorganik birikmalardan tashkil topgan adsorbent materiali (CHCFe) suvli eritmalardan konqo-qizilni olib tashlash uchun ishlatilgan. Jarayon spontan va ekzotermikdir. Adsorbsion jarayoni ikki bosqichda (konqo-qizil molekulalarining CHCFe ga massaviy migratsiyasi va rang beruvchi molekulalarning ichki g‘ovaklar orqali ichki difuziyasi) o‘tkazildi. Langmuir modeli bo‘yicha 50 °C da CHCFe tomonidan maksimal konqo-qizil qabul qilish 1649,3 mg/g ni tashkil etgan.

XULOSA

Xulosa o‘rnida aytish mukinki, yuqorida sanab o‘tilgan usullar bilan Fe asosida Fe-BTC, MOF-235, CHCFe adsorbentlarini olish jarayoni murakkab emas. Shu bilan birga olingan namunalarning har birida g‘ovaklilik darajasi yuqori bo‘lib, kongo qizil, metal oranj, metilen ko‘ki kabi anionik va kationik organik bo‘yoqlarni adsorbsiya qilish orqali suvdan ajratishda yuqori samadorlikni namoyon qilgan.

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