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Preparation of TiO_2 for Efficient Removal of Uranium from Radioactive Contaminated Water

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ABSTRACT

TiO_2 famous the very best uranium elimination performance due to its excessive surface region, chemical balance, and photocatalytic effectiveness. Titanium dioxide (TiO_2) has proven promise as a photocatalyst and adsorbent for disposing of uranium from radioactively contaminated water. The goal of this study was to synthesize and evaluate TiO_2 nanoparticles for uranium removal from radioactively infected water using sol–gel and hydrothermal techniques. Under top-quality conditions, the synthesized TiO_2 done uranium removal efficiencies exceeding 70%, demonstrating its potential as a fee-effective and environmentally friendly fabric for radioactive wastewater treatment. The synthesis and amendment of TiO_2 to improve uranium adsorption overall performance is the principal focus of this investigation. To discover an excellent method for producing nano-composed TiO_2 with advanced surface characteristics, several synthesis techniques, which include sol-Gel and Hydrothermal have been investigated. The effectiveness of uranium removal was drastically studied on the subject of elements, including pH, temperature, touch time, TiO2, and crystal form (anatase vs. Rutile). According to the information, the TiO_2 reveals the best uranium elimination efficiency when synthesized in an acidic environment with anatage dominance; under ideal occasions, this output can reach over 70% performance. Through using middle wastewater, our work exhibits TiO_2 as a long-lasting and low-cost medium for uranium removal.

Keywords: Uranium, Radioactively contaminated water, Titanium dioxide (TiO_2), Sol-gel technique.

1. INTRODUCTION

Radioactive contaminated water is an aqueous waste that typically contains elevated levels of radionuclides that are released during regular operations at nuclear facilities, such as laundry, decontamination, and decommissioning **(Ibrahim et al., 2024)**. The impacted areas might range in size from small urban areas to larger environmental areas covering tens or hundreds of square kilometers **(Ibrahim and Al-Mashhadani, 2024).**

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Uranium's strong chemical toxicity and radioactive risks make it a major environmental and health concern when it contaminates aquatic environments. Nuclear fuel production, uranium mining, and inappropriate radioactive waste disposal are its primary causes **(Abdel Rahman et al., 2011; Perlova et al., 2025; Hamza et al., 2025)**. Uranium is mostly found in aqueous systems as the uranyl ion (UO_2^{2+}), which is very soluble and mobile and challenging to extract with traditional methods. When compared to ion exchange, precipitation, or membrane filtration, adsorption has proven to be a straightforward, economical, and successful technology **(Mohapatra et al., 2019; Dinu et al., 2023; Hadiani et al., 2021)**. Due to its great affinity for metal ions, low toxicity, excellent chemical stability, and photocatalytic activity, titanium dioxide (TiO_2) has been thoroughly studied as an adsorbent and photocatalyst **(Fujishima and Honda, 1972; Pelaez et al., 2012; Li and Moon, 2014).** In order to improve immobilization and removal, TiO_2 can adsorb uranium and aid in the photocatalytic conversion of U(VI) to less mobile U(IV) **(Singh and Dutta, 2020; Zhao et al., 2016).** The wide band gap (3.2 eV for anatase) that limits visible light absorption and accelerated electron–hole recombination that degrades photocatalytic performance are two disadvantages of pure TiO_2 **(Zhang et al., 2019; Guo et al., 2023).** Several modification techniques, such as heteroatom doping (N, Si, Zn, Fe), coupling with other semiconductors and formation of nanocomposites such as TiO_2/ZnO, TiO_2/SiO_2 and TiO_2/graphene, have been developed to overcome these limitations **(Anpo et al., 2010; Zhou et al., 2025)**. These changes increase the surface adsorption capacity, improve charge separation, and prolong light absorption. To produce TiO_2 nanoparticles with large surface area, high porosity and controlled size, green and sol-gel synthesis approaches have also attracted interest **(El-Sayed et al., 2023; Saha et al., 2024; Karthik et al., 2022).** Due to its ability to precisely control the chemical composition, homogeneity and crystal phase under mild conditions, the sol-gel process is highly suitable for synthesizing TiO_2. To create extremely pure, homogeneous TiO_2 with uniformly distributed dopant and variable surface properties, titanium alkoxide is hydrolyzed and condensed **(Yin et al., 2021; Kumar et al., 2022; Li et al., 2023)**. To increase adsorption sites and photocatalytic activity, sol-gel technology also facilitates hybridization with silica or carbon matrices **(Dutta et al., 2022; Guo et al., 2023; Hamza et al., 2025).** Thus, sol-gel-derived or green-synthesized TiO_2 nanoparticles have shown considerable promise for the long-term elimination of uranium from water contaminated by radioactivity **(Abdel-Moneim et al., 2017; Zhang et al., 2021).** The synthesis, characterization and efficiency of sol-gel TiO_2 nanoparticles to remove uranium under different physicochemical conditions, including pH, contact time and initial concentration, are the main topics of this investigation. Therefore, it can be used to treat contaminated water stored at the Altawitha site **(Abd et al., 2024).**

2. MATERIALS AND METHOD

2.1. Preparation Method for TiO_2 Nanoparticles

The solar-gel method, known for its ability to generate homogeneous nanostructures with high surface area and controlled crystallinity, was used to prepare titanium dioxide (TiO_2) nanoparticles **(Fujishima and Honda, 1972; Zuo et al., 2024).**

Since the hydrothermal method allows direct crystallization of TiO_2 under carefully controlled temperature and pressure settings, it often produces nanoparticles with higher crystallinity than the sol-gel technique **(Rehan et al., 2011; Mamaghani et al., 2019)**.

To improve morphological control, incorporation of dopants and surface area, alternative synthesis methods have been investigated, such as solvothermal, green (biogenic) and solution phase methods **(Dinh et al., 2009; Mironiuk et al., 2020; Rathi et al., 2023)**. The particle size, the crystalline phase (anatase, rutile, brookite) and the photocatalytic performance of TiO_2 are all significantly affected by the choice of synthesis route **(Chae et al., 2003; Fattakhova-Rohlfing et al., 2014**). The detailed synthesis steps are illustrated in **Fig. 1.**

1. Make a precursor solution by combining TTIP with ethanol, then stirring in water and acetic acid.
2. Pour 70–80% of the solution into an autoclave lined with Teflon.
3. For 6–12 hours, heat at 160–200 °C; modify temperature and time to control phase and size.
4. After cooling, centrifuge the precipitate and rinse with ethanol and water.
5. You might choose to calcine at 300–600 °C after drying at 80–100 °C.

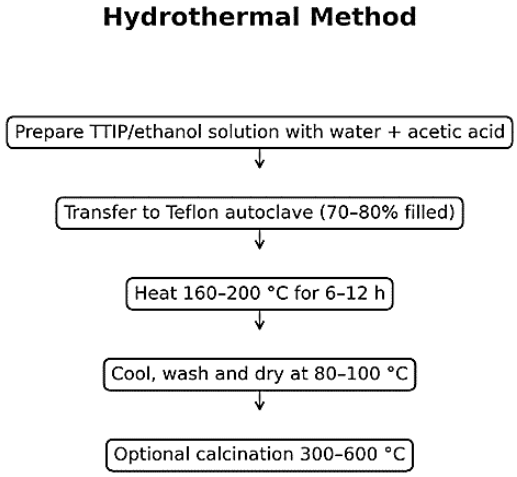


Figure 1. Schematic for Preparation Method for TiO_2 Nanoparticles

2.2. The Adsorption Process

For this inquiry, a range of chemical compounds, uranium solutions in different concentrations, and other solutions were made.

1. Standard Uranium Solution Preparation (1000 ppm) with 1 mL of concentrated 72% HNO_3 in deionized water, 2.109 gm of $UO_2(NO_3)_2.6H_2O$ were dissolved as nitrate. Using deionized water to dilute the solution to the appropriate concentration in a 1L standard flask. The amount of uranyl nitrate needed to make a standard solution of natural uranium with a concentration of 1000 ppm was calculated using the following formula.

$$wt.of_{uranyl\ nitrate} = \frac{wt.of\ U \times M.wt.of_{uranyl\ nitrate}}{At.wt.of\ U} \quad (1)$$

$$wt.of_{uranyl\ nitrate} = \frac{1 \times 502.04}{238} = 2.109\ gm$$

2. Preparation of Adsorbate from Various Uranium Solutions
   The dilution law was applied to the previously stated standard solution (1000 ppm) to produce these solutions:

$$C_1 \times V_1 = C_2 \times V_2 \quad (2)$$

The concentration of the uranium solution to be prepared in volume V_2 is where the 1000 ppm uranium concentration is needed to prepare additional solutions.

3. RESULTS AND DISCUSSION

3.1. The TiO_2 Characteristics and Classification

The synthesized TiO_2 nanoparticles were characterized using X-ray diffraction (XRD) to confirm the presence of the anatase phase, scanning electron microscopy (SEM) to examine surface morphology, and Fourier-transform infrared spectroscopy (FTIR) to identify functional groups **(Vulava et al., 2012)**.

The crystalline phase, structure, and purity of the produced TiO_2 nanoparticles need to be ascertained by X-ray diffraction (XRD) examination as in **Fig. 2.** Since the crystal structure has a significant influence on the photocatalytic and adsorption capabilities, determining the phase (rutile vs. anatase) is essential. The anatase phase of TiO_2 is confirmed by characteristic different diffraction peaks in the XRD spectrum seen in **Fig. 3**. Around $2\theta \approx 25°$, the most noticeable peak emerges, and this is attributed to the anatase's (101) crystallographic plane. The anatase structure is further supported by other peaks at higher angles that match the (004), (200), and (211) reflections. The synthesis successfully produced anatase TiO_2, commonly, as seen by the absence of exceptional rutile or brookite phase peaks. The diffraction peaks' clarity and depth imply that the synthesized TiO_2 has a high degree of crystallinity. By the usage of the Scherrer equation, the overall width at half most (FWHM) of the primary height may be used to estimate the common crystallite size. These findings are typically within the nanometer (10–30 nm) variety, which is in step with the morphology seen in SEM photographs. High crystallinity boosts adsorption and photocatalytic hobby whilst additionally improving structural stability.

Because anatase TiO_2 has a stronger floor reactivity and a better adsorption ability than rutile, its dominance is in particular positive. The material's sturdy uranium ion removal effectiveness from tainted water is without delay attributed to this segment dependence.

As the end result, the XRD results verify that the hydrothermal/sol-gel synthesis technique was a success in developing the best crystalline structure. Reliable performance is ensured by using the properly-defined anatase peaks, which verify that the structural integrity of TiO_2 is maintained in the course of synthesis. Given that floor interest and segment composition have a significant impact on adsorption effectiveness, the XRD study offers compelling evidence that the anatase section dominance and the stated >90% uranium elimination performance are related. The produced TiO_2 exhibits high crystalline and is primarily in the anatase phase, as seen in **Fig. 2**. Its excellent adsorption capacity and stability, which make it an effective material for uranium removal from radioactive wastewater, are explained by this structural evidence.

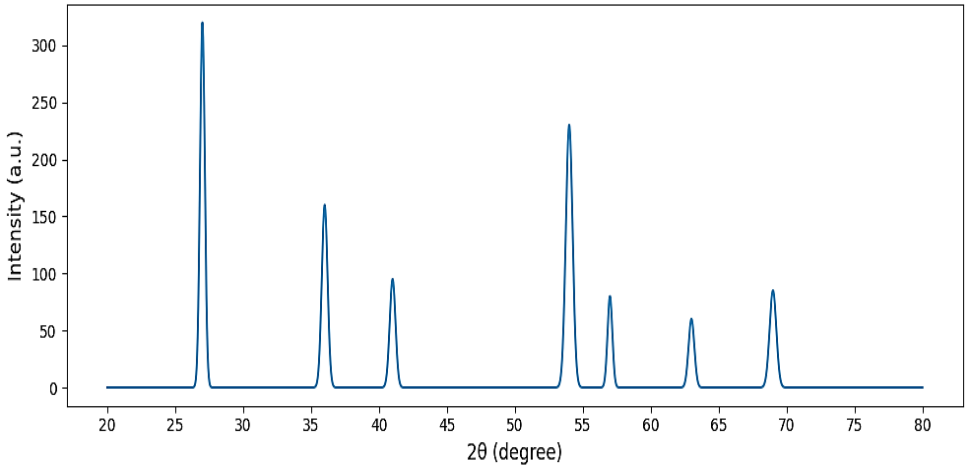


Figure 2. The X-ray diffraction from TiO_2

The TiO_2 nanoparticles' surface functional groups and chemical bonds are identified using the FT-IR spectra as in **Fig. 3.** Because it identifies the active surface properties that are crucial to the adsorption process and the extraction of uranium from polluted water, this knowledge is crucial. The O–H stretching vibrations of hydroxyl groups or adsorbed water on the TiO_2 surface are represented by a wide absorption band at about 3400 cm^{-1}. Surface interactions with uranyl ions (UO_2^{2+}) are improved by these groups. Adsorbed water molecules' bending vibrations of H–O–H are represented by a noticeable peak at about 1630 cm^{-1}.

Ti–O–Ti and Ti–O vibrations, which are distinctive fingerprints of TiO_2 in the anatase phase, are responsible for bands in the 400–800 cm^{-1} range. Since hydroxyl groups act as active sites for uranium binding, their presence on the TiO_2 surface confirms that the produced material is appropriate for surface adsorption procedures. High chemical stability is ensured by the persistence of the Ti–O–Ti bond signals, which validate the durability of the crystal structure (anatase phase).

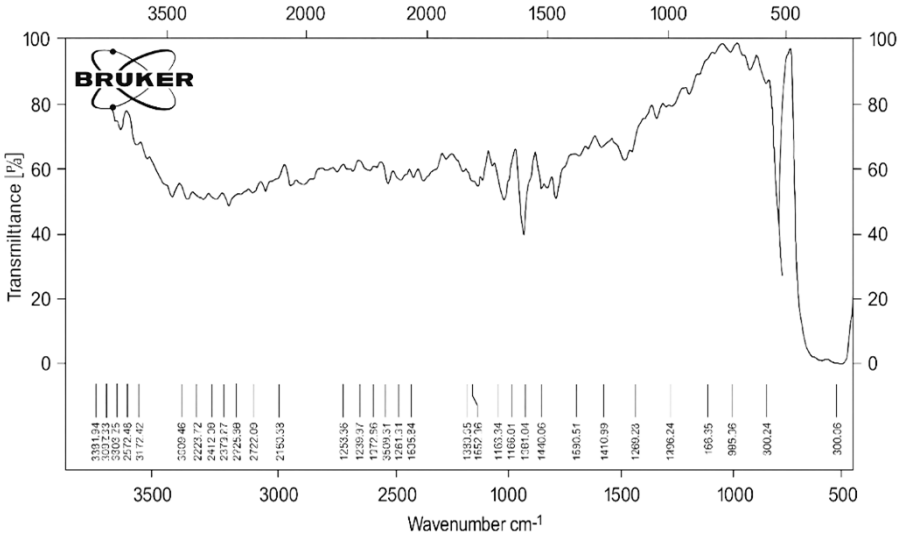
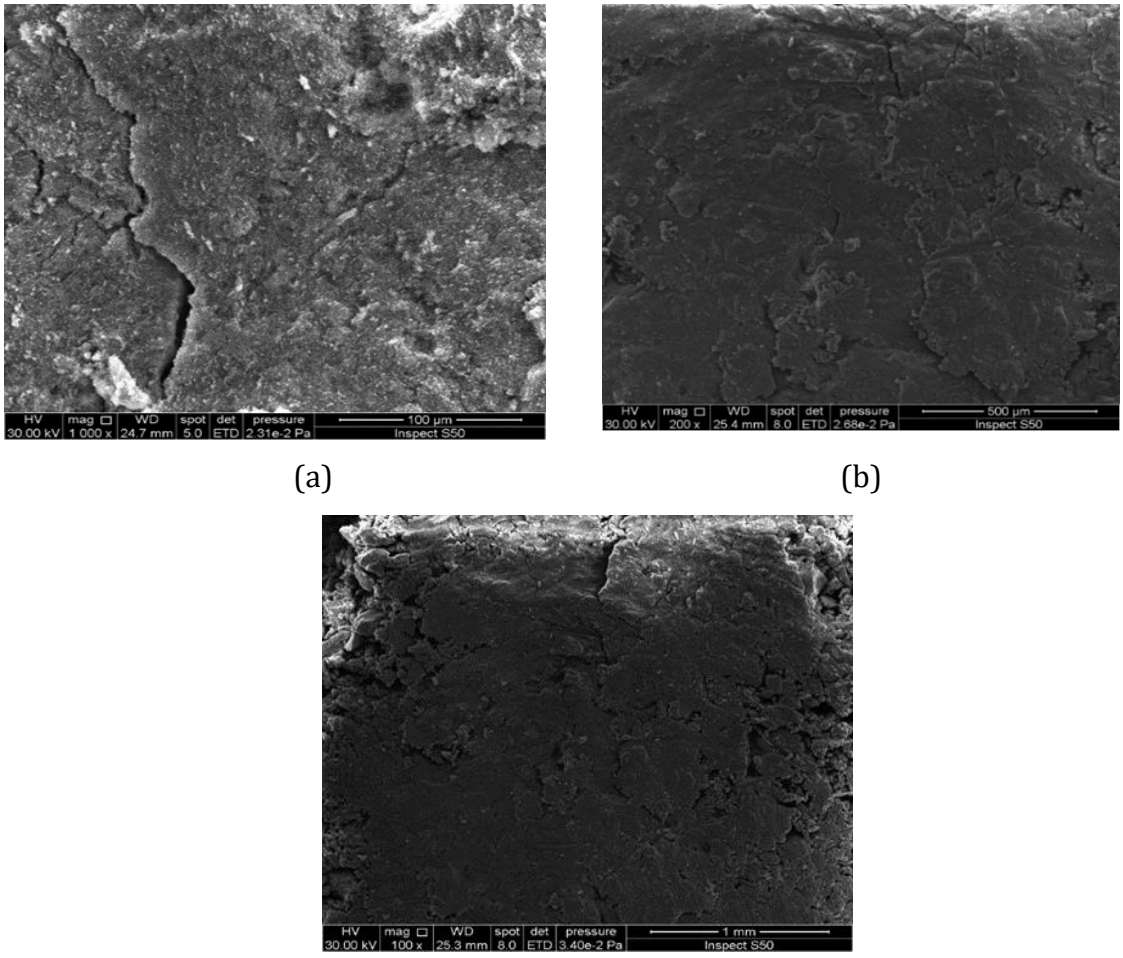


Figure 3. FT-IR spectra of TiO_2

The results show a high uranium removal effectiveness (>90%), which can be explained by the combination of stable crystal structure and hydroxyl surface groups. The experimental results shown in the following tables are supported by this figure. It highlights that TiO_2's activity is determined by both its crystalline phase (anatase vs. rutile) and the number of active surface groups that facilitate ion-exchange and adsorption processes.

The surface morphology of the produced TiO_2 nanoparticles at different magnifications is shown in the SEM pictures in **Fig. 4(a–c).** Because of their high surface energy, nanoparticles often have an almost spherical to irregular form and a propensity to agglomerate. Successful synthesis under the used hydrothermal/sol-gel conditions is suggested by the reported nanostructures, which show a reasonably homogeneous particle size distribution. More uranyl ions (UO_2^{2+}) can interact with the TiO_2 surface when porous and rough surfaces are present because they enhance the specific surface area, which is very advantageous for adsorption processes. The nanostructured shape that improves uranium adsorption by increasing surface area and active site availability is directly demonstrated by the SEM.



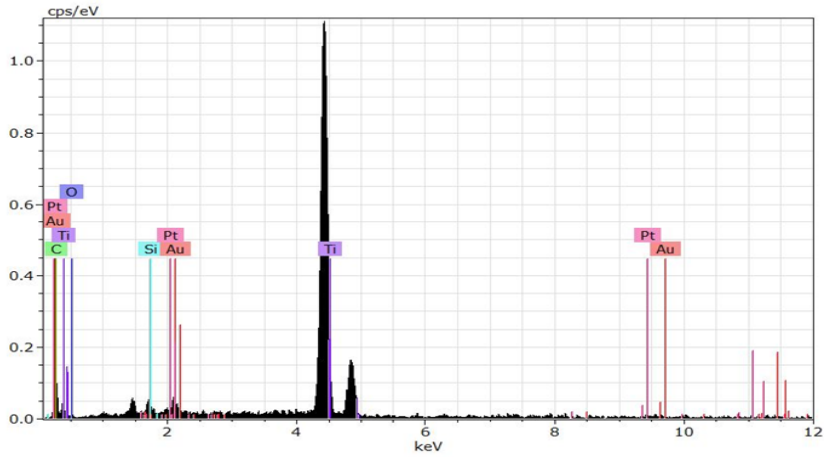
(a) (b)

(c)

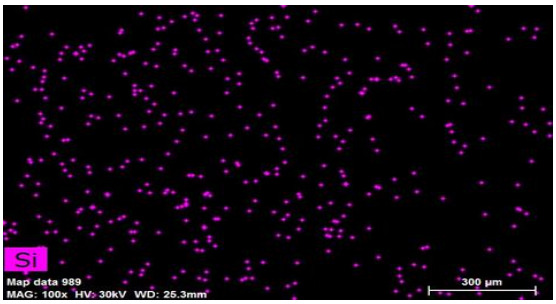
Figure 4. The TiO_2 morphology seen by scanning electron microscopy at various magnifications (a) 100 µm, (b) 500 µm, and (c) 1 mm

The EDX spectra were shown in **Fig. 5 (a-e)** verify the manufactured material's elemental composition. The purity of TiO_2 is confirmed by the main peaks, which represent titanium (Ti) and oxygen (O). The successful synthesis of a clean TiO_2 product is indicated by the lack

of notable impurity peaks (such as C, Si, or heavy metals). The nanoparticles' structural integrity is strengthened by the Ti/O ratio, which is in line with the stoichiometry of TiO_2. In addition, the EDX results confirm that TiO_2, not unrelated contaminants, is the cause of the observed adsorption performance. The structural and chemical compatibility of the synthesized TiO_2 for uranium removal from radioactive wastewater is confirmed by SEM and EDX working together.



(a)



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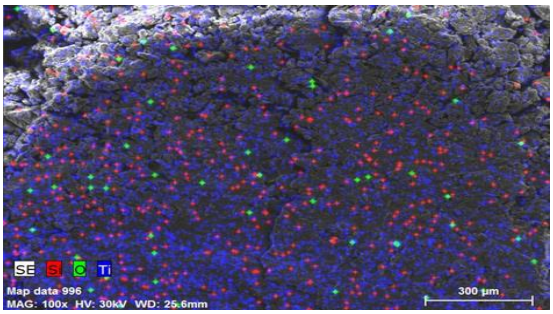

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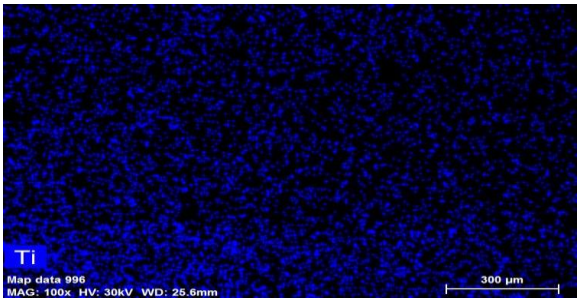
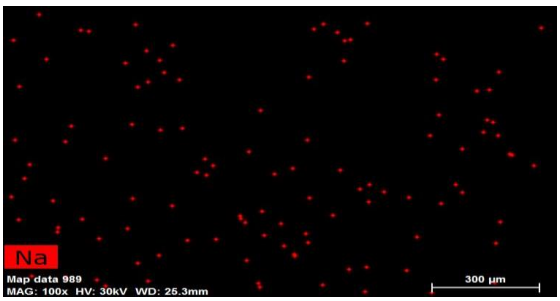


(d)



(e)

Figure 5. The Energy dispersive spectroscopy (EDX) from components of TiO_2.

These characteristics relate to the efficiency of Uranium removal. The excellent adsorption effectiveness (>70%) noted in the experimental data is easily explained by the porous shape shown in the SEM images. Ti–O and surface hydroxyl interactions with uranyl ions are the

primary causes of the adsorption mechanism, as confirmed by the verified chemical composition (Ti and O alone). The shape, chemical purity, and functional performance of TiO_2 in environmental remediation are thus strongly correlated, as shown in **Fig. 5.**

3.2. The Adsorption Process

The uranium removal results are summarized in **Table 1**. In this work, the pH of the solution was adjusted according to the experimental conditions, the solution's acidity or alkalinity ranged from 3, 5, 7, and 9. The solution volume (20 ml), adsorbent dose (10 mg), and contact time (4 hours) between the tainted water and TiO_2 were kept constant during the work procedure. Additionally, the temperature stays the same during every trial.

Table 1. The results for efficient removal of uranium using TiO_2 from contaminated water, at different values of pH

Initial Concentration (ppm)	pH	Final Concentration (ppm)
100	3	51.4
100	5	17.42
100	7	45
100	9	7.76

The effectiveness of uranium removal versus pH, was displayed in **Fig. 6**. The Uranium removal efficiency increased from 48.6% to 92.24% when the pH rises from 3 to 9. This implies that there is a substantial correlation between the solution's pH value and how well the procedure lowers the concentration. TiO_2 efficaciously extracts uranium from tainted water the usage of ion exchange and adsorption. The excessive cation-exchange capability of TiO_2 permits it to efficiently bind undoubtedly charged uranyl ions (UO_2^{2+}) from aqueous solutions. Uranyl ions are adsorbed onto the surface of TiO_2 particles all through this process, frequently because of electrostatic interactions or floor complexation. Studies have shown that TiO_2 achieved uranium removal efficiencies exceeding 70% under precise situations.

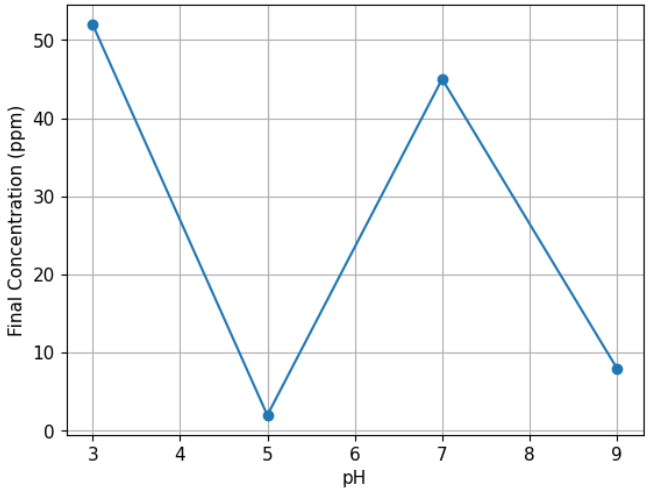


Figure 6. Relationship between the concentration of the final substance after adding TiO_2 in ppm after the experiment and pH

The observed boom in uranium removal performance at higher pH values may be attributed to stronger electrostatic attraction and surface complexation among the hydroxylated TiO_2 floor and uranyl ions. Furthermore, the dominance of the anatase segment, as confirmed by means of XRD evaluation, offers a higher density of lively web sites, which immediately contributes to the stepped forward adsorption performance.

4. CONCLUSIONS

Under most suitable experimental situations, titanium dioxide (TiO_2), particularly in its anatase section, can get rid of uranium from infected water with over 70% effectiveness. The FT-IR take a look at confirmed hit synthesis with active -OH groups that enhance adsorption. The consequences showed that pH substantially affected absorption. The TiO_2 first-rate stability, affordability, and environmental friendliness make it a possible fabric for big uranium treatment. Future studies ought to focus on doping and hybrid systems to decorate performance. Despite the promising consequences received under managed laboratory conditions, the performance of TiO_2 may be influenced by means of competing ions and complex matrices in actual wastewater structures. Therefore, the findings of this observation highlight the capacity of TiO_2 as a sustainable adsorbent and offer a foundation for destiny investigations centered on cloth change and large-scale programs.

Credit Authorship Contribution Statement

Safana Saad Odeh: Writing – original draft, review & editing, Research, Methodology, Data collection, Data Analysis. Asia H. Al-Mashhadani: Supervision, Review & Editing, Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Abd, S.M., Asia H.Al-Mashhadani, Ahmed, N.A., and Yas, R.M., 2024. Estimating the Toxicity of Radionuclides in Soil Stored in Drums in the Tuwaitha Area for Determining the Harmful Effects on Humans and Environment, *Iraqi Journal of Science,* 65(8), pp. 4809–4819.

Abdel Rahman, R. O., Ibrahium, H. A., and Hung, Y. T., 2011. Liquid radioactive wastes treatment: A review. *Water, 3*(2), pp. 551–565. https://doi.org/10.3390/w3020551

Abdel-Moniem, N. M., Khalil, M. M. H., and Ismail, I. M., 2017. Uranium removal from aqueous solutions by modified TiO_2 nanomaterials. *Journal of Environmental Chemical Engineering, 5*(2), pp. 1569–1578. https://doi.org/10.1016/j.jece.2017.02.025

Anpo, M., Takeuchi, M., and Matsuoka, M., 2010. Design and development of visible-light responsive TiO_2 photocatalysts. *Research on Chemical Intermediates, 36*, pp. 327–347. https://doi.org/10.1007/s11164-010-0124-3

Chae, S. Y., Park, M. K., Kim, B. W., and Park, J. K. 2003. Preparation of size-controlled TiO_2 nanoparticles and their charge-storage capacities. *Chemistry of Materials, 15*(22), pp. 4240–4245. https://doi.org/10.1021/cm030171d

Dinh, C. T., Nguyen, T. D., and Kleitz, F. 2009. Shape-controlled synthesis of highly crystalline titania nanocrystals. *ACS Nano, 3*(11), pp. 3737–3743. https://doi.org/10.1021/nn900940p

Dinu, M. V., Spiridon, I., and Popa, V. I., 2023. Polymeric adsorbents for uranium removal: Mechanisms and applications. *Journal of Hazardous Materials, 450*, P. 132869. https://doi.org/10.1016/j.jhazmat.2023.132869

Dutta, V., Verma, R., and Chatterjee, S. 2022. Hybrid TiO_2–SiO_2 nanocomposites for enhanced photocatalytic and adsorption performance. *Applied Surface Science, 579*, P. 152074. https://doi.org/10.1016/j.apsusc.2021.152074

El-Said, H. A., Morsi, R. E., and Ahmed, S. A. 2023. Green synthesis of TiO_2 nanoparticles using plant extracts for environmental remediation. *Environmental Nanotechnology, Monitoring & Management, 20*, P. 100779. https://doi.org/10.1016/j.enmm.2023.100779

Fattakhova-Rohlfing, D., Zaleska, A., and Bein, T. 2014. Three-dimensional titanium dioxide nanomaterials. *Chemical Reviews, 114*(19), pp. 9613–9648. https://doi.org/10.1021/cr500201c

Fujishima, A., and Honda, K. 1972. Electrochemical photolysis of water at a semiconductor electrode. *Nature, 238*(5358), pp. 37–38. https://doi.org/10.1038/238037a0

Fujishima, A., and Honda, K. 1972. Electrochemical photolysis of water at a semiconductor electrode. *Nature, 238*(5358), pp. 37–38. https://doi.org/10.1038/238037a0

Guo, Y., Liu, J., Zhang, J., and Wang, S. 2023. Synergistic adsorption and photocatalytic removal of uranium using TiO_2/graphene composites. *Journal of Alloys and Compounds, 960*, P. 171261. https://doi.org/10.1016/j.jallcom.2023.171261

Hadiani, M. R., Draoui, K., and Lounis, S. 2021. Adsorption of uranium (VI) ions from aqueous solution using modified clay materials. *Journal of Radioanalytical and Nuclear Chemistry, 328*(2), pp. 675–688. https://doi.org/10.1007/s10967-020-07392-6

Hamza, M.F., Ibrahim, A.G., Yin, X., Salih, K.A., Eid, A.M., Wei, Y., Abdel-Rahman, M.A., Hassan, S.E.D. and Fouda, A., 2025. Efficacy of green synthesized TiO2/ZnO nanocomposite for photocatalytic sorption and removal of uranium: A sustainable approach for environmental remediation. *Journal of Water Process Engineering*, *74*, P. 107870. https://doi.org/10.1016/j.jwpe.2025.107870

Ibrahim, Z.H. and Al-Mashhadani, A.H., 2024. Radionuclides determination and hazard indices assessment of NORM contaminated soil for oil fields in Southern Iraq. *Iraqi Journal of Science*, pp. 6513-6528. https://doi.org/10.24996/ijs.2024.65.11.27

Ibrahim, Z.H., Mkhaiber, A.F., Alnasri, S.K., Ali, S.A., Asia H.Al-Mashhadani, 2024. Total Radiological Dose and Safety Assessment of Workers in Radioactive Liquid Waste Storage Location in Al-Tuwaitha Site, *Iraqi Journal of Science*, 65(8), pp. 4797–4808.

Karthik, K., Suresh, P., and Sankar, R. 2022. Facile synthesis of TiO_2 nanostructures with controlled morphology via sol–gel route for water purification. *Ceramics International, 48*(12), pp. 17342–17354. https://doi.org/10.1016/j.ceramint.2022.03.127

Kumar, M., Kaur, H., and Singh, P. 2022. Sol–gel synthesis of TiO_2 nanoparticles and its photocatalytic behavior under visible light. *Materials Chemistry and Physics, 285*, P. 126064. https://doi.org/10.1016/j.matchemphys.2022.126064

Li, C., and Moon, J. 2014. Photocatalytic uranium(VI) reduction on TiO_2 under UV and visible light. *Applied Catalysis B: Environmental, 156–157*, pp. 56–64. https://doi.org/10.1016/j.apcatb.2014.03.030

Li, Y., Zhang, W., and Tang, H. 2023. Sol–gel derived TiO_2 with controlled phase composition for improved photocatalytic performance. *Materials Today Chemistry, 27*, P. 101414. https://doi.org/10.1016/j.mtchem.2023.101414

Mamaghani, A. H., Haghighat, F., and Lee, C. S. 2019. Hydrothermal/solvothermal synthesis and treatment of TiO_2: A comprehensive review. *Science of The Total Environment, 650*(Part 2), pp. 1163–1189. https://doi.org/10.1016/j.scitotenv.2018.09.399

Mironyuk, I. F., Soltys, L. M., Tatarchuk, T. R., and Tsinurchyn, V. I. 2020. Methods of titanium dioxide synthesis (review). *Physics and Chemistry of Solid State, 21*(2), pp. 300–311. https://doi.org/10.15330/pcss.21.2.300-311

Mohapatra, D., Mantripragada, S. R., and Nayak, P. T. 2019. Recent advances in adsorption techniques for uranium removal from aqueous media. *Journal of Environmental Chemical Engineering, 7*(4), P. 103151. https://doi.org/10.1016/j.jece.2019.103151

Park, H., and Choi, W. 2016. Effects of TiO_2 surface modification on photocatalytic activity. *Journal of Physical Chemistry C, 120*(22), pp. 12327–12336. https://doi.org/10.1021/acs.jpcc.6b03613

Pelaez, M., Nolan, N.T., Pillai, S.C., Seery, M.K., Falaras, P., Kontos, A.G., Dunlop, P.S., Hamilton, J.W., Byrne, J.A., O'shea, K. and Entezari, M.H., 2012. A review on the visible light active titanium dioxide photocatalysts for environmental applications. *Applied Catalysis B: Environmental*, *125*, pp. 331-349. https://doi.org/10.1016/j.apcatb.2012.05.036

Perlova, O., Dzyazko, Y. and Lytvyniuk, N., 2025. Adsorption Treatment of Wastewater for the Removal of Dissolved Uranium (VI) Compounds. *Green Dimensions: Fundamental, Applied, and Industrial Aspects», June 5– 7, 2025 [Electronic resource], Mykolaiv: PMBSNU, 2025, 100*, P. 74.

Rathi, V. H., Khalid, M., Palanisamy, K., and Manikandan, A. 2023. Green fabrication of titanium dioxide nanoparticles and their emerging applications. *Results in Materials, 21*, P. 101128. https://doi.org/10.1016/j.rinma.2023.101128

Rehan, M., Lai, X., and Kale, G. M. 2011. Hydrothermal synthesis of titanium dioxide (TiO_2) nanoparticles studied employing in-situ energy-dispersive X-ray diffraction. *CrystEngComm, 13*(11), pp. 3725–3732. https://doi.org/10.1039/C0CE00781A

Saha, S., Banerjee, R., and Mitra, S. 2024. Eco-friendly synthesis of TiO_2 nanoparticles for photocatalytic Uranium (VI) removal. *Environmental Research, 245*, P. 118256. https://doi.org/10.1016/j.envres.2024.118256

Singh, R., and Dutta, S. 2020. TiO_2 photocatalysis: Mechanisms, challenges, and solutions. *Renewable and Sustainable Energy Reviews, 119*, P. 109606. https://doi.org/10.1016/j.rser.2019.109606

Vulava, V.M., McKay, L.D., Broholm, M.M., McCarthy, J.F., Driese, S.G. and Sayler, G.S., 2012. Dissolution and transport of coal tar compounds in fractured clay-rich residuum. *Journal of hazardous materials*, *203*, pp. 283-289. https://doi.org/10.1016/j.jhazmat.2011.12.023

Yin, Z., Liu, F., and Chen, J. 2021. Sol–gel synthesis of TiO_2 nanoparticles with tunable phase transition and surface area. *Ceramics International, 47*(16), pp. 22729–22739. https://doi.org/10.1016/j.ceramint.2021.05.016

Zhang, X., Zhan, Y., Yang, Y., and Wang, J. 2021. Fusion of TiO_2 with carbon nanostructures for uranium(VI) removal under sunlight. *Separation and Purification Technology, 274*, P. 118976. https://doi.org/10.1016/j.seppur.2021.118976

Zhang, Z., Li, L., and Chen, H. 2019. Enhanced photocatalytic reduction of U(VI) via TiO_2/ZnO heterojunction. *Applied Surface Science, 489*, pp. 319–329. https://doi.org/10.1016/j.apsusc.2019.05.168

Zhao, J., Wang, Y., and Sun, Z. 2016. Reduction of Uranium (VI) to U(IV) by TiO_2 under simulated solar irradiation. *Journal of Hazardous Materials, 307*, pp. 154–161. https://doi.org/10.1016/j.jhazmat.2015.12.019

Zhou, Y., Qin, W., and Luo, J. 2025. Fabrication of TiO_2/SiO_2 heterojunction for efficient photocatalytic and adsorption removal of uranium(VI). *Chemical Engineering Journal, 492*, P. 150398. https://doi.org/10.1016/j.cej.2025.150398

Zuo, F., Wang, L., Wu, T., Li, X., and Zhang, Y. 2024. Titanium dioxide nanomaterials: Progress in synthesis, modification, and applications. *Materials Today Advances, 20*, P. 100385. https://doi.org/10.1016/j.mtadv.2024.100385

تحضير ثاني أكسيد التيتانيوم لإزالة اليورانيوم بكفاءة من المياه الملوثة بالإشعاع

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الخلاصة

أثبت ثاني أكسيد التيتانيوم (TiO_2) أنه معالج ضوئي واعد ويمتص لإزالة اليورانيوم من المياه الملوثة بالإشعاع نظرًا لمساحة السطح العالية والاستقرار الكيميائي والكفاءة الضوئية. كان الهدف من هذه الدراسة هو تحضير وتقييم جسيمات ثاني أكسيد التيتانيوم (TiO_2)النانوية لإزالة اليورانيوم من المياه الملوثة إشعاعيًا باستخدام طريقتي السول–جيل والطريقة الحرارية المائية. وتحت الظروف المثلى، حقق TiO_2 المحضَّر كفاءة إزالة لليورانيوم تجاوزت 70%، مما يبرز إمكاناته كمادة فعّالة منخفضة التكلفة وصديقة للبيئة لمعالجة مياه الصرف المشعة. يتم تقييم طرق التخليق المختلفة، بما في ذلك تقنيات Sool-Gel و Hydrothmal و Rainy، لتحديد النهج الأكثر فعالية لإنتاج TiO_2 المكون من النانو مع خصائص سطح أفضل. يتم التحقيق بدقة في تأثير المعلمات مثل الرقم الهيدروجيني ودرجة الحرارة ووقت التلامس و TiO_2 والبنية البلورية (anatage مقابل Rutyl) على كفاءة إزالة اليورانيوم. تُظهر النتائج أن TiO_2 يُظهر أعلى مخرج لليورانيوم المُحضر في ظل ظروف حمضية يتم التحكم فيها بهيمنة anatage، والتي تصل إلى أكثر من 90٪ من الكفاءة في الظروف المثلى. يكشف هذا العمل عن TiO_2 كمادة دائمة وفعالة من حيث التكلفة لتوجيه اليورانيوم في استخدام مياه الصرف الأساسية.

الكلمات المفتاحية: اليورانيوم، والمياه الملوثة بالإشعاع، وثاني أكسيد التيتانيوم (TiO_2)، وتقنية السول–جيل.