

Identification of Magnetic Fe₃O₄ Nanoparticles by Artemisia Absinthium Extract

Abstract

Nanomaterials have become one of the innovative research directions in materials science, biochemistry, and medicine. Small nanoparticles (NPs) lead to the development of branches of science in very small-scale dimensions, such as nanotechnology ushering in more advanced levels of research in its field. Fabrication and use of nanometer-sized materials are increasingly growing, considering their interesting industrial properties; however, nanoparticles taken from chemical compounds are now focused attention in research as they may contain hazardous and toxic chemicals and may generate risks when applying green chemistry principles. This study aimed to identify magnetic Fe₃O₄ nanoparticles by Artemisia absinthium extract.

FT-IR, FESEM, and XRD TEM techniques were used to identify the synthesized nanoparticles. The parameters examined in this study included removal time, pH, and level of nanoparticles; each was 15-45 minutes, 5-9, 0.1-0.05 grams, respectively. The findings from a real sample suggested a 70% removal which consequently increased as the nanoparticle level rose by up to 0.1 gram. Under standard conditions, 94.78% and in a real sample, up to 71% of tetracycline was removed from the medium. The findings showed that a significant portion of tetracycline could be removed by Artemisia absinthium extract-modified magnetic Fe₃O₄ nanoparticles, making this research a practical work in sewage treatment plant-related issues.

Keywords: *Magnetic nanoparticles, Fe₃O₄, Iron oxide, Artemisia absinthium, Tetracycline, Aqueous solutions*

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Introduction

Nanotechnology or nanotech is the use of matter on an atomic, molecular, and supramolecular scale for industrial purposes. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules to fabricate macroscale products, also known as molecular nanotechnology. Nanotechnology is among the most modern technologies in the world that enjoys unique characteristics and is widely applied in all fields of science. Nanotechnology research is one of the important emerging aspects whose application in science and technology aims to produce new materials at the nano-scale level (1).

Nanoparticles are widely applied in advancing treatments and diagnosis of diseases. A nanoparticle or ultrafine particle is usually defined as a particle of matter between 1 and 100 nanometers in diameter. Nanoparticles such as nanoliposomes, carbon nanotubes, nanofibers, nanospheres, and nanoparticles are largely used for drug carriers and cell scaffolding. Nanoparticle application in drug delivery includes drug carriers in diseases such as cancer, cardiovascular diseases, and Alzheimer's. The use of these nanocarriers for neurological diseases such as Alzheimer's has proven to be very effective because due to their size, these nanoparticles can go through the blood-brain barrier, which always inhibits drug delivery to the damaged area in this type of destructive brain disease. Due to their small sizes, nanoparticles serve as the main target in brain cancers. Currently, nanoproducts are largely accepted as biocompatible materials. These materials are also used in

surgery, dentistry, neuronal cell, and biomolecular research. The second branch of nanotechnology focuses on designing and fabricating mechanical systems at a molecular level to be used in medicine. Nanotechnology has proven to be very reliable for modern medicine due to increased treatment strategies (2). In general, various types of nanoparticles include metal nanoparticles, metal oxides, carbon nanomaterials, and nanocomposites (3).

Magnetic nanoparticles have diverse applications such as membrane production, power generation, materials fabrication, data storage, and medical engineering (4). Included in such applications are oxide (magnetic) Fe₃O₄ nanoparticles, which serve as the most important category of magnetic particles, and are focused attention by researchers not only for their extraordinary properties such as ideal sizes and suitable physical and chemical properties that depend on the form of these particles but also for their high biocompatibility and superparamagnetic properties. Iron oxide nanoparticles are largely used to prevent the accumulation and co-precipitation of materials in biological fields such as Magnetic Resonance Imaging (MRI) (5). The conventional form of iron oxide is magnetism. These nanoparticles are slightly toxic and biocompatible. Magnetic iron nanoparticles are highly reactive and easily subjected to degradation by direct contact with the environment. Magnetite nanoparticles involve many hydroxyl groups on their surface. Hydroxyl groups adsorbed on the surface of magnetite nanoparticles are active agents that react with acid or base; thus, the chemistry of the magnetite particle's surface is highly dependent on the pH of the environment.

Also, hydroxyl groups react with other organic and inorganic anions, adsorbing cations or protons on them. It was previously suggested that magnetite nanoparticles had high magnetic properties and greater surface area, thus tending to coagulate and oxidize. The process of surrounding nanoparticles through protective agents is critical to prevent this. The stability of the colloidal suspension due to the protective factors will result from a balance between repulsive and gravitational forces (6). The smaller size of the particles in nano-scale creates new and different properties compared to agglomerated materials as researchers highly focus on it. Nanoparticles, especially iron nanoparticles, account for a significant contribution to this field, influencing various fields of science and industry. Fabrication and use of nanometer-sized materials are increasingly growing, considering their interesting industrial properties; however, nanoparticles from chemical methods used today are focused attention in research as they may contain hazardous and toxic chemicals and that may be associated with the risks from applying green chemistry principles which have caused increased concern; hence, the production of these nanoparticles using the green chemistry principles has assumed a special status in research areas.

However, Fe₃O₄ nanoparticles tend to agglomerate and cluster with each other due to their strong polar-polar magnetic adsorption property. Therefore, materials such as surfactants, oxides, metal nanoparticles, or polymer compounds with specific functional groups stabilize the Fe₃O₄ nanoparticles.

On the other hand, it is important to remove TC residues before discharging the wastewater; as a result, advanced and reliable technologies will be needed to remove antibiotics (8).

There is so much concern about tetracycline (Tc) because of its potential genetic effects, aquatic ecosystem erosion, antibiotic resistance enhancement, neutral bio-degradation, and source of hazardous contamination. Due to its physical and chemical properties, TC is a polar annular molecule subjected to oxidation and has different low pH values, creating ionic compounds of various structures. Thus, considering myriad annular structures in aqueous solutions, finding ways to effectively remove TC from aqueous media will be necessary. Until now, numerous technologies, including photocatalytic degradation, ion exchange, and adsorption, have been applied to remove antibiotics from aqueous solutions (9).

Apart from the toxicity of veterinary antibiotics to organisms, the long-term presence of antibiotics in the environment could develop antibiotics for ARB-resistant bacteria and ARG-resistant genes. Nanometer-sized materials are increasingly used due to their intriguing properties. However, nanoparticles taken from these methods could expose the environment to potential perils due to chemically hazardous materials, radioactivity, reactivity under certain conditions (temperature and pressure), expensiveness, and time-consuming processes.

Therefore, there is an increasing need for a low-cost method without producing toxic substances to prevent environmental damage. One of the techniques to produce nanoparticles is biological (green) production which is currently under focus. Since they are compatible with the environment, plants are popular as they do not damage the environment. Also, plants are considered an ideal option for biologically producing nanoparticles as they are abundant and do not need special conditions and nutrients for growth (10).

Researchers have focused on green materials and methods to produce nanomaterials in recent decades. They were working on producing nanomaterials using non-toxic chemicals used in green synthesis (11).

Our studies focused on *Artemisia absinthium*. *Artemisia absinthium* is an *Artemisia* species native to temperate regions of Eurasia [6] and Northern Africa and widely naturalized in Canada and the northern United States.[7] It is grown as an ornamental plant and used as an ingredient in the spirit absinthe and some other alcoholic beverages. Common names for various species in the genus include mugwort, wormwood, and sagebrush. It is also one of the most diverse groups in the Asteraceae plant family, involving over 500 species of aromatic substances. It is also effective in pharmaceutical-food-environmental industries.

These significant biological activities are associated with antimicrobial or antiseptic-insecticide and antioxidant properties. The development of new and alternative nanoparticle techniques without using nanoparticles but through eco-friendly pathways has led to using plant extracts as reducing and stabilizing agents in aqueous solutions (biological reduction). (12). Several species have unique medicinal facts that strengthen pharmaceutical industry economics (13).

Ghasemi et al. (2019) successfully worked on an ultrasound-assisted solid-phase extraction of parabens from environmental and biological samples using magnetic hydroxyapatite nanoparticles as an efficient and regenerable nano sorbent. Magnetic hydroxyapatite nanoparticles (@ HAP γ -Fe₂O₃) were a suitable adsorbent for pre-adsorption and adsorption. Parabens are, in particular, methyl-, ethyl-, propyl-, butyl-, pentyl-, phenyl- and benzyl parabens (14).

In 2019, Maria del Pilar Rodriguez et al. successfully showed the antibacterial properties of *Artemisia*-based silver nanoparticles against three *Candida* species. Silver nanoparticles were synthesized in five different ratios using the bio-green reduction method by blending silver nitrate and aqueous *Artemisia absinthium* extract. A reduction trend of silver nitrate was noted against the increasing *Artemisia absinthium*. The *absinthium* aqueous extract was successfully used as a biological reducing and stabilizing agent (15).

investigated the oil composite of 5 *Artemisia* species for chemotherapy. This examination analyzed the EO essential oils extracted from dehumidified aerial parts of the 5 species. EO was performed to test the chemical significance of the essential oil made of *Artemisia* species. EO of all other *Artemisia* species signifies the integration of EOs with molecular data. One would conclude that the use of phytochemical-chemotherapeutic, anatomical, morphological, and karyological analyses coupled with new molecular methods of other *Artemisia* species will demonstrate a clearer infrgeneric classification. It is critical to provide relative quantitative and qualitative evolutionary processes as the *Artemisia* oil composite coupled with molecular data as a chemical factor can be used to understand *Artemisia* species (16).

Elham Aseman Bashiz et al. (2019) investigated the application of the Electro-Fenton process, including Fe^{+2} and Fe^{+3} heterogeneous catalysts, to remove ciprofloxacin from aqueous solutions. The findings suggested that the Electro-Fenton process was able to remove ciprofloxacin from aqueous solutions. Despite the presence of Iron (II) sulfate heptahydrate as a source of iron in the Electro-Fenton process, the removal efficiency was almost greater than when magnetite nanoparticles were used as a source of iron; thus, since magnetite can be recycled and reused, it is better to use magnetite in experiments as a source of iron (17).

Adriana Magdalena Hawards-Felix et al. (2018) removed tetracycline contaminants by magnetic adsorption separation method using reduced graphene oxide decorated with α - Fe_2O_3 nanoparticles. RGO nanomaterials coupled with α - Fe_2O_3 nanoparticles were fabricated in situ by heat treatment. Studies on the structural and morphological behavior demonstrated that the reduced oxygen functional group in RGO affected the surface chemistry following heat treatment and the presence of α - Fe_2O_3 nanoparticles on the RGO surface. The tetracycline adsorption on RGO depended on pH values, where the maximum adsorption was 38.55 mg/g, 328.8 mg /g, and 58.14 mg/g at pH 7, 10, and 4, respectively. The tetracycline adsorption on the α - Fe_2O_3 /RGO nanocomposite decreased, respectively (18).

Luo & Giankiu et al. (2018) investigated the effect of particle size on norfloxacin and tetracycline adsorption. Their findings revealed that particle size significantly affected antibiotic adsorption onto SPM in rivers, where the strongest adsorption capacity of 150-63 was noted, with the lowest capacity seen at 300 μm (19).

Wilfredo Marimon Boulevard et al. (2018) investigated green synthesis by increasing magnetism and evaluating the life cycle of Fe_3O_4 nanoparticles. The technique proposed glutathione as a precursor and stabilizer of the magnetic nanoparticles synthesis. This type of precursor yielded higher

efficiency when producing magnetic nanoparticles. This material enjoys high colloidal stability and saturation magnification. The saturation magnification will achieve the maximum value in the particles as captured by conventional methods, such as synchronized precipitation. A free eSH group layer will coat glutathione-synthesized Fe_3O_4 nanoparticles allowing an efficient action of heavy metals adsorption, especially the mercury in contaminated waters. However, it is noted that the rate of oxidation effect and magnetic loss of colloidal dispersion using magnetic nanoparticles will significantly decrease (20). As stated in this study, magnetic Fe_3O_4 nanoparticles were identified by *Artemisia absinthium* extract.

Research Methods

At first, 30 grams of *Artemisia absinthium* was added to 100 ml of deionized water. Then it was stirred with a magnetic stirrer for 4 hours at 90°C and centrifuged and smoothed to separate impurities and solid particles. The extract was used to make an iron oxide nanoparticles-synthesized catalyst. The resulting extract was then removed by filter paper. The required amount was about 100 ml.

The co-precipitation technique was applied to synthesize magnetic iron oxide nanoparticles. FeCl_2 and FeCl_3 were combined to reconstitute magnetic Fe_3O_4 iron oxide nanoparticles. Working in laboratory research, $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ and $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ were first added to 100 ml of deionized water and blended by a mechanical stirrer at a suitable temperature under the effect of nitrogen. Consequently, a suitable volume of ammonium hydroxide was injected into the blend; later, it was separated from the nanoparticles when the base was added to the iron salt solution, and a chemical precipitate was formed. The *Artemisia absinthium* extract was refluxed for 6 hours with synthesized magnetic nanoparticles. The solution was then centrifuged, and the resulting precipitate was removed. Accordingly, to identify the nanocatalyst, electron microscopes and other identification techniques such as FT-IR-FESEM-TEM-XRD were utilized. Serving as a recyclable and heterogeneous nanocatalyst, we used it to remove tetracycline from aqueous media.

We put the drug in it for a while. Antibiotics removal by synthesized nanoparticles was examined and optimized by chemometrics to achieve the highest efficiency from the possible parameters (e.g., the level of nanoparticles, temperature, and time) affecting the removal of the antibiotic. Under optimal conditions, antibiotic removal in an aqueous medium was examined. UV-Vis spectroscopy was used to measure the degradation of antibiotic removal bonds. Superparamagnetic iron nanoparticles are widely used inorganic materials in pharmaceutical industries which can be manufactured using such chemical methods as co-precipitation or biological techniques.

Identification of Fe₃O₄ adsorbent profile using FT-IR, XRD, and SEM techniques

FT-IR spectrum

IR spectra were used to identify the functional groups in the Fe₃O₄ adsorbent and determine the successful modification process of the iron nanoparticle surface. To reconstitute the sample to capture the IR spectrum, 0.01 g of Fe₃O₄ adsorbent was mixed and made uniform in an agate mortar, and after the IR spectrum was made, the sample was captured in the 4000-400 cm⁻¹ range.

XRD spectrum

In this study, an Xpert model XRD apparatus developed by Phillips was used. For analytical diffraction studies, a crystalline sample is usually ground to become a fine homogeneous powder; in this study, since the studied sample is a nano-sized adsorbent, no grind is needed. Samples are poured into a capillary tube of thin-walled glass and exposed to X-rays. After the diffraction pattern is determined, it must be analyzed.

To this end, the available phases were identified by comparing the XRD diffraction angle and the relevant level of intensity with the values provided by ASTM cards and Xpert software.

SEM

SEM analysis is most popular for surface analysis. The SEM microscope is the most common type of electron microscope. This microscope examines the microstructure of materials by scanning the surface via electron beams, and like light microscopes, it enjoys high-level resolution and much greater depth. Moreover, the SEM electron microscope, if equipped with an EDX, provides sample chemical data in various ways.

TEM

Due to their shorter wavelength of electrons than light wavelength, Transmission Electron Microscopy (TEMs) are capable of higher-resolution imaging than optical microscopes; therefore, they can image microstructural materials with a magnification of 1,000 to 1,000,000 and a resolution of less than 1 nanometer. Transmission electron microscopy can also qualitatively and quantitatively analyze the elements and determine the crystal structure as small as 30 nanometers.

Examining the effect of adsorbent on adsorbing tetracycline from a real sample

Laboratory or hospital effluent can serve as a real sample. The first step is filtration and centrifugation to separate and

sediment all suspended particles in the solution; this will be very effective in achieving a true adsorption value. Then, the UV apparatus is used to measure the solution adsorption in tetracycline by λ_{max} . The adsorption value from the effluent is then compared with the adsorption value of the standard 10 ppm tetracycline solution; afterward, the effluent, taking the difference of values into account, will be diluted, or the optimal conditions can be equally changed.

After the effluent is diluted, 10 cc of it is taken and poured into a beaker. According to the optimal conditions shown by the test design, it is added to the nanoparticle solution with the tetracycline removal process performed just like removal under standard conditions.

Finally, the solution adsorption is taken to measure the removal of tetracycline from the real sample.

Findings

Identification of Fe₃O₄ magnetic nanoparticles using Artemisia absinthium extract

IR spectrum

FT-IR spectrum reveals qualitative data which is key in identifying functional groups of materials. On the other hand, it also helps identify the type of bonds in a compound.

The FT-IR spectrum demonstrates magnetic Fe₃O₄ nanoparticles. Comparison of this spectrum with reference values in the articles demonstrates the accuracy of Fe₃O₄ in the compound obtained. The surface structure of the material was demonstrated using a Fourier transform infrared spectroscopy. Figure 1a illustrates magnetic iron nanoparticles and Figures 1b and c Artemisia absinthium-coated magnetic iron nanoparticles. In Figure 1b, the band at 3400 cm⁻¹ pertains to the OH group, and the surface waters adsorbed on the surface of the magnetic iron nanoparticles. The adsorption band at less than 700 pertains to the Fe-O bond in iron oxide. The band at 1400 suggests the presence of Fe₃O₄ structure and the absence of other iron structures such as hematite. At peak b, bands at 300 and 1400 pertain to the carbonyl group and carbon-oxygen bond. The stretching vibration adsorption band of C-H appeared at 600 cm⁻¹.

In the second peak, the adsorption band displacement of the 1500 to 1300 band suggested the presence of a dual carbon band. Here, spectrum C shows the coordination of alcohol and oxygen groups to iron oxide.

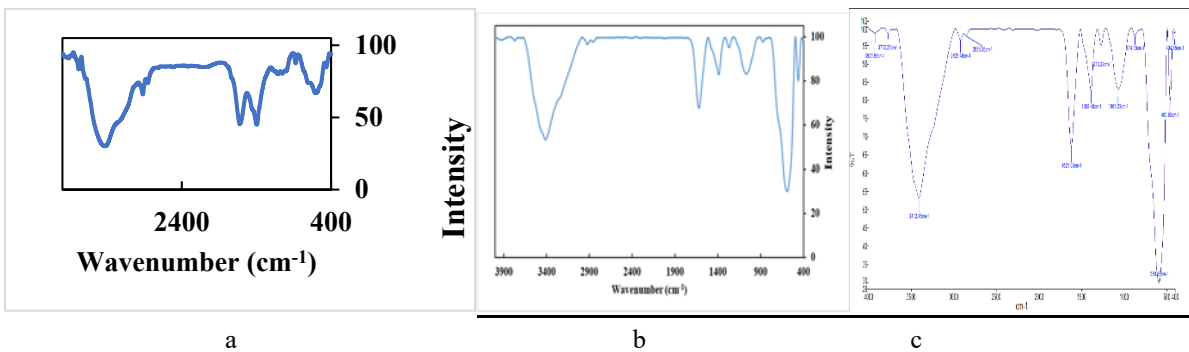


Figure 1- a) FT-IR spectrum of magnetic Fe_3O_4 nanoparticles, b) FT-IR spectrum of magnetic Fe_3O_4 nanoparticles modified by Artemisia absinthium extract, c) FT-IR spectrum of magnetic Fe_3O_4 nanoparticles coated with Artemisia absinthium extract

As seen in Figure 1a, only the Fe-O bond is a tetrahedron with the octahedral and OH surface water adsorbed on Fe_3O_4 . According to Figure 1b, at 3400, the band is a single O-H branch, and the double-branch and wide O-H band extends from 2400 to 3400 and turns acidic. Otherwise, if it extends to 3400 from 3200, it becomes alcoholic. The C = C bond is 1500 to 1600, and the C = O bond shows approximately 1700. As shown in Figure 1c, the O-H:3412.46 bond, C = C:1621.03 bond, C-H:1388.48 bond, and C-O-H:1069.23 are seen.

XRD spectrum

Here, the diffraction pattern of the crystal lattice of iron metal is demonstrated. Fe Miller indices are either octahedral or tetrahedral.

The strong peaks which appeared at 30000° , 35000° , 45000° , 60000° , 65000° , correspond to diffractions (1100000), (1600000), (1100000), (1200000), (1300000), respectively, and pertain to Fe_3O_4 , illustrated in each diagram. (The peaks diagram with the main peaks in JCPDS 89-3854 was compared for identification.) The result demonstrated that the catalyst had been successfully synthesized without damaging the Fe_3O_4 core structure. Examining the diagram, the wide peak at 17° - 25° pertains to the shell of the Artemisia absinthium extract on the surface of magnetic nanoparticles.

The number of 6 peaks pertaining to Fe_3O_4 ($2\theta = 30.1, 35.4, 43.0, 53.5, 57.0, 62.5$) are illustrated in the figure. These 6 peaks pertain to 6 crystal plates of 220,311,400, 422, 511, and 440 (Figure 2).

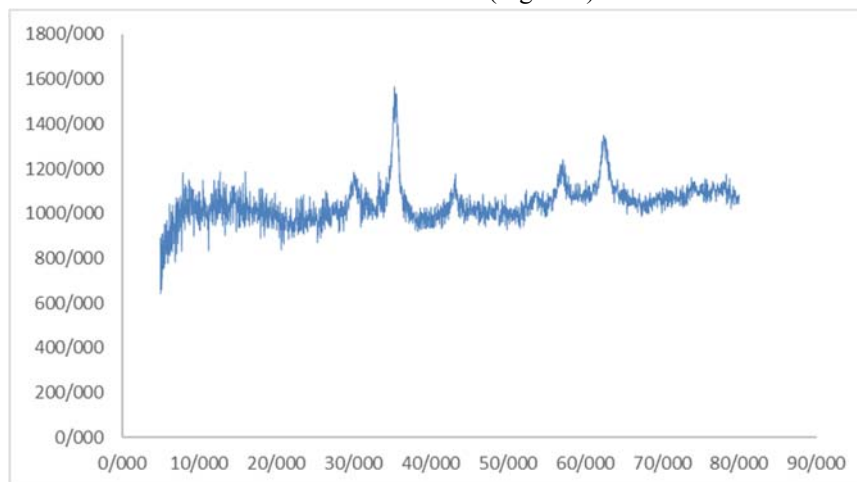


Figure 2 - XRD spectrum of Artemisia absinthium extract-modified magnetic Fe_3O_4 nanoparticles

SEM spectrum

SEM images of magnetic nanoparticles reconstituted after the co-precipitation process were taken to determine the diameter, size, morphology, cavity structure, and cross-section. The following figure illustrates the reconstituted iron oxide magnetic nanoparticles morphological structure. The FESEM image of the synthesized Fe_3O_4 catalyst demonstrates that the catalyst was made of uniform nano-scale particles. It is quite clear that the particles are completely spherical. Moreover, particle density is noted in some areas, possibly due to inter-

particle magnetic interaction. As for SEM, WDX provides qualitative information about the distribution of various chemical elements in the catalyst matrix. Figure 3a shows the images taken by the SEM, which corresponds to the (WDX) elemental mapping for the synthesized catalyst, indicating that the shell structure of iron oxide nanoparticles core is composed of the Artemisia absinthium shell, which is well dispersed in the catalyst. They also have a size of 20 to 50 nm. Here, the topology and morphology of the surface are demonstrated, i.e., the ridges indicating the Artemisia absinthium plant is loaded.

In other words, it refers to all the flavonoids, biopolymers, and terpenoids on the plant and the Fe_3O_4 substrate. Figure 3c demonstrates the substrate-like structure and the surface-to-

volume ratio. It also shows the dimensions of the magnetic Fe_3O_4 nanoparticles used in the catalyst, with dimensions of approximately 100 nm.

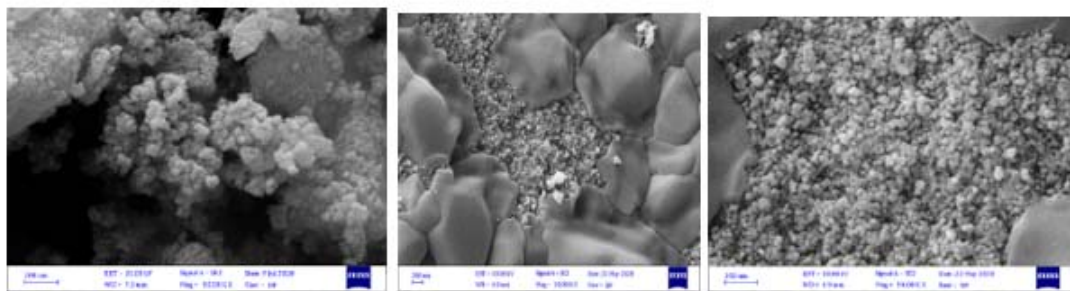


Figure 3 - a) SEM of magnetic Fe_3O_4 nanoparticles, b) SEM of magnetic Fe_3O_4 nanoparticles, c) SEM of magnetic Fe_3O_4 nanoparticles coated with Artemisia absinthium

TEM spectrum

Figure 4 demonstrates the crystal lattice size. The figure also illustrates the core-shell structure (dark core: Fe_3O_4). The faint

halo around the core shell pertains to the nanoparticles-loaded plant extract.

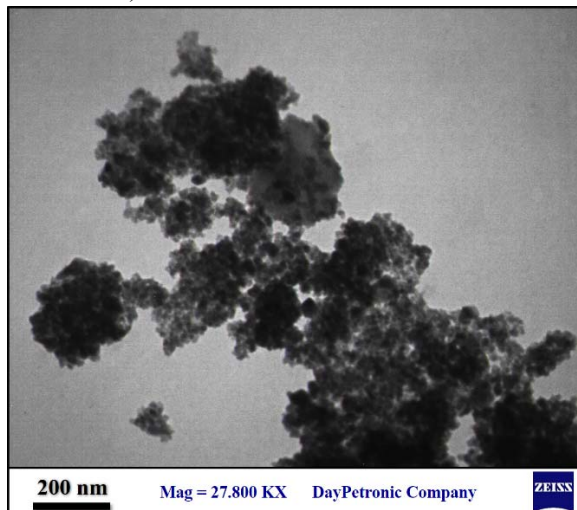


Figure 4) TEM of magnetic nanoparticles

EDX Spectrum

The EDS (EDX, EDXS, or XEDS) spectrum is used to identify the elements existing in nanoparticles. As seen in Figure (5a), Fe, C, and O peaks demonstrate these elements' presence in the Fe_3O_4 nano catalyst-synthesized nanoparticles. The elemental composition by the EDX analysis and the data from the

following figure demonstrates the signals of carbon, nitrogen, oxygen, and iron. Looking at Figure 5, the presence of N, Fe O, and C elements is evident. In Figure 5, which demonstrates the presence of N, O, and C, this method examines the interaction between an X-ray excitation source and a Fe_3O_4 sample.

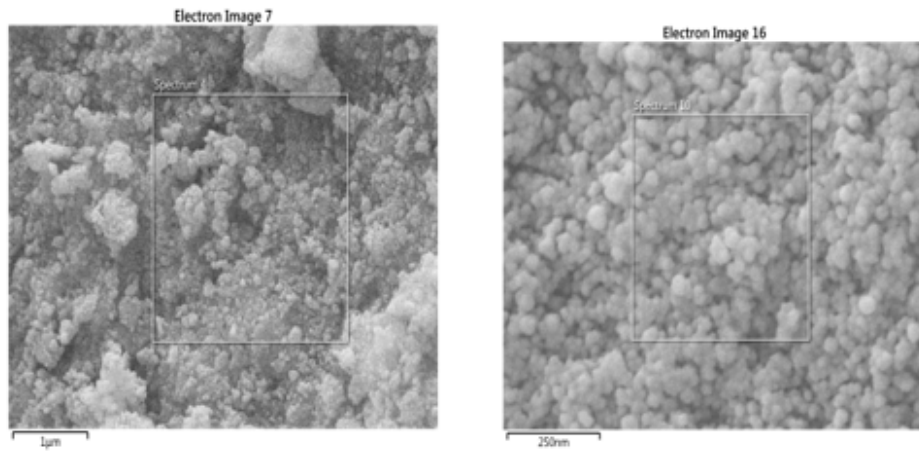


Figure 5 - a) EDS of magnetic Fe₃O₄ nanoparticles, b) EDS of magnetic Fe₃O₄ nanoparticles coated with Artemisia absinthium

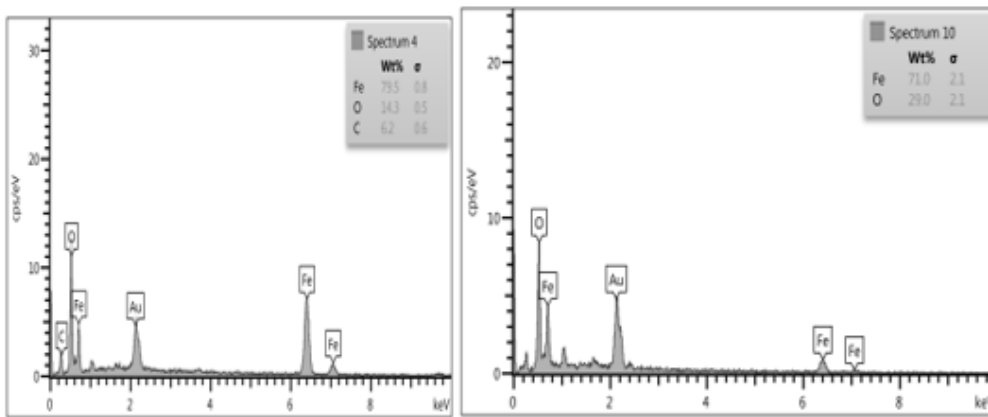


Figure 6- a) EDX of magnetic Fe₃O₄ nanoparticles, b) EDX of magnetic Fe₃O₄ nanoparticles coated with Artemisia absinthium

MAP-ANALYSIS spectrum

This spectrum shows the frequency distribution of elements present in a composite. The following image demonstrates the

elemental mapping of the oxygen, iron, and carbon composition. It also illustrates that the carbon present inside the plant is on the Fe₃O₄ substrate (Figure 7).

EDS Layered Image 4

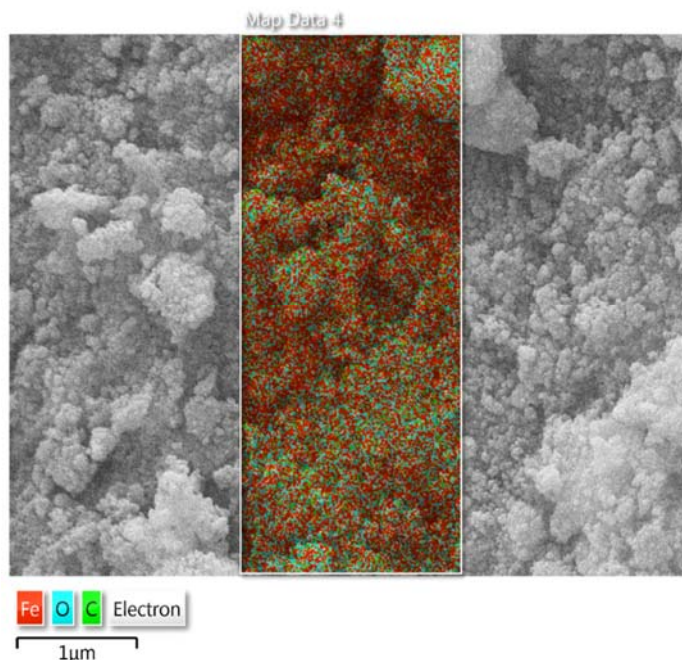


Figure 7: Mapping spectrum of Fe₃O₄ nanoparticles coated with Artemisia absinthium

Examining the pH effect

As it is clear, the steady-state with a longer half-life in tetracycline is neutral at pH as it moves toward hydrolysis, dehydration, and other chemical reactions in acidic and alkaline environments.

In acidic environments, however, hydrogen separated from the acid replaces the OH and O electron pair groups in tetracycline. The more acidic it is, the greater this replacement becomes. Consequently, the electron pair is occupied and fails to enter the hydrogen bond. It is suggested that under acidic environments, they lack a hydrogen bond acceptor group, ultimately causing the hydrogen bond not to be established properly and adsorption to decrease.

However, unlike acidic environments, basic environments refer to situations where the hydrogens of the hydroxyl group are lost, and the composition lacks a hydrogen bonding donor group. The more basic the environment, the lower the number

Table 1: Examination of the efficiency of the real sample removed by Artemisia absinthium extract-modified magnetic Fe₃O₄ nanoparticles

Test	Adsorption	Removal efficiency
Initial effluent after dilution	0.235	-
Applying optimal conditions on initial effluent	0.09	61.70
Gradual increase of nanoparticles of 0.145 g	0.07	70.21

Conclusion

of hydrogens, yielding less hydrogen bonding and lower attachment of the two compositions, ultimately causing reduced adsorption.

Thus, the best condition in this test is the neutral pH, where both the hydrogen-bonding donor and the acceptor exist.

Examining the efficiency of synthesized nanoparticles on a real sample

Aside from the optimal conditions, the experiment was repeated on the real sample. Laboratory effluent was then taken to serve as the real sample.

After being filtrated and centrifuged, the real sample was diluted with deionized water and the adsorption amount at $\lambda_{\max} = 264$ nm was initially 0.09. Then, considering the much interference and the nanoparticle capacity being filled up, we achieved an absorption rate of 0.07. by gradually increasing the level of nanoparticles (Table 1).

Magnetic nanoparticles generally contain such magnetic elements as iron, cobalt, nickel, and their chemical compounds.

Examining the safety or toxicity of these particles is of great importance when using magnetic nanoparticles in foodstuffs. Therefore, considering different types of magnetic nanoparticles, iron oxide nanoparticles, especially superparamagnetic (magnetite Fe_3O_4) nanoparticles, are mostly used in the food industry due to their non-toxicity, good biocompatibility, and non-remanence of residual magnetism after being removed from the external magnetic field. Experiments have demonstrated that:

1. Due to its superparamagnetic properties, high specific surface area, surfactants (active service agents), high stability at different pH, ease of synthesis, and removal from aqueous solutions under a magnetic field, magnetic Fe_3O_4 adsorbent can be considered an effective and bio-compatible agent and also an ideal option to remove tetracycline from effluents.
2. In addition to ionic bonds, the sequential presence of hydroxyl and carbonyl functional groups in tetracycline makes it possible for these two substances to be easily adsorbed.
3. The nanoparticle parameter's effect was greater than that of the other two parameters, suggesting the different efficiency of the adsorbent in different amounts.
4. Increasing the gram-based amount of Fe_3O_4 adsorbent will produce some good effects on efficiency, however reducing the removal efficiency afterward.
5. Contact time on the test process was positive; however, the changes were not significant relative to the changes in the amount, and since the desired answer was achieved in 15 minutes, the test process ceased. The optimal contact time was taken to be 15 minutes.
6. The highest adsorption efficiency was noted at neutral pH, and this was also due to the type of tetracycline structure and its instability at alkaline and acidic pHs.

Because concerns are mounting about the presence of different types of drugs in the effluent, it is suggested to consider different types of drugs. It is suggested that software calculations of this study be performed to yield accurate information on how these two compounds interact.

However, this research faced limitations in that it used the UV-vis device. Moreover, examining the real sample, one could not demonstrate that the tetracycline was adsorbed due to the presence of other compositions that might show adsorption at the same tetracycline wavelength.

Acknowledgments

None.

Conflict of interest

None.

Financial Support

None.

Ethics Statement

All Permissions to conducting this research has been approved.

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