Evaluation of the effectiveness of Fe_3O_4 nanoparticles and sand filtration in removal of TDS, SO_4, Cl and HCO_3 in Aquifer Bahr Al-Najaf

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ABSTRACT

This study was conducted to evaluate the efficacy of Fe3O4 nanoparticles and sand filter in removing total dissolved solids (TDS), Sulfate (SO_4), chloride (Cl), (HCO_3) in Bahr al-Najaf aquifer. Groundwater Samples were collected from a well in Bahr al-Najaf region to analyze some physical and chemical parameters (includes total dissolved solids, sulfates, chloride and bicarbonate). The results showed nano iron oxide has the following removal efficiency: 76.3 for TDS, 64% for SO4, 87.5% for HCO3 and 82.8% for Cl. However, the sand filter has much lower removal rates compared to nano iron oxide, with 3.7%, 5.3%, 50% and 3.5% for the mentioned pollutants, respectively.

Key wards: Ground Water, Fe_3O_4, Nanoparticle, Al- Najaf. Aquifer.

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INTRODUCTION

The nanotechnology can be considered as a relatively new branch of modern science that deals with the synthesis, design, and manipulation of nanoscale particles. This technology was defined by [(1)] as the study, development, and application of materials with a diameter of 1 to 100 nanometers. The synthesis of nanoscale materials, as well as the discovery of their unique physical, chemical, and optoelectronic properties, have all been made possible by remarkable advances in nanotechnology. Monodisperse nanoparticles with a diameter of less than 100 nm are in high demand for a variety of industrial applications [(2)]. Nanotechnology has been applied to tackle difficulties with water quality and quantity. Nanomaterials are assisting in the construction of more effective treatment techniques in advanced water treatment systems. The technology of Nano can be utilized to remedy a range of water quality issues to ensure environmental stability [(3, 4)]. By comparing conventional and non-conventional technologies, several studies [(5,6)] have shown that nanotechnology can be used to purify water and improve the environment much better compared to conventional water treatment methods which are ineffective in removing pollutants that exist in low concentrations. Furthermore, traditional treatment procedures are frequently energy-intensive, and they produce a lot of sludge and relatively dangerous waste. Nanotechnology may thus become increasingly essential, particularly for the removal of certain toxin pollutants. In addition to many other benefits, nano-based techniques enable for reuse, need less space, and can prevent the development of harmful intermediates [(7,8)]. Many nano-based treatment technologies have been proven to be effective as supplements or replacements for treatment methods unlike traditional forms of technology [(9,10,11)]. During the past few years, researchers, who are preparing and studying materials, have increased their interests on metal nanoparticles due to their increased applications [(12)]. It was found that the different properties of these metals will change dramatically at nanoscale compared to conventional approaches, reaching a complete change with properties [(13)]. A study by [(14)] indicated that Nano Iron is super-magnetic and one of the elements which is very interesting due to its many applications in advanced technologies, as it is widely used in many applications, including the removal of pollutants and ions of toxic heavy metals from water. Because iron-based nanoparticles have various properties such as surface modifiability by various substances and functional groups, the removal mechanism of a specific contaminant is usually achieved simultaneously a combination of physic-chemical adsorption, reduction, precipitation, and disinfection [15,16].

MATERIAL AND METHODS

STUDY AREA

The groundwater samples for this study were taken from a well south-west of Najaf City, which is located at latitudes of (29o 50 - 32o 21) and longitudes of (42o 50 - 45o 44) and 160 km south of Iraq's capital, Baghdad (Fig.1). It has a population of more than a million with a total area of 28,824 km [17]. The majority of the soil in the study region is sand with high porosity and permeability, enabling groundwater to flow in distinct ways based on the topography of the area. The study area has very hot and dry weather during summer months and relatively cold during winter [18].

Figure 1: Location of the study area and sampling locations

SAMPLE ANALYSIS

TDS parameter was measured, as physical water quality parameter according [19], by using digital portable multimeter (model 340i/SET, WTW, Germany) while, SO_4 was determined by using turbidity method, Bicarbonate and Cl- was measured by titration method.

SYNTHESES OF MAGNETIC IRON NANOPARTICLES

Highly magnetic iron oxide nanoparticles ($Fe_3O_4MNP_s$) were prepared using Co-precipitation method which can be summarized as follows:

1- Mix 2 ml of HCl at a concentration of 1.5 molars with 250 ml of deoxygenated distilled water.
2- The molar ratio of 2:1 of ferric ions (fe^{+3}) and binary iron ions (fe^{+2}) was prepared by mixing 6.5 g of $FeCl_3$ salt with 5.56 g of $FeSo_4.7H_2O$ salt and added to the solution prepared in the first step with continuous stirring.
3- Added 500 ml of NaOH solution with a concentration of 1.5 mol to the above solution in the form of drops with continuous and rapid stirring. It was noticed that a black precipitate of highly magnetic iron oxide (magnetite) (supermagnatic Fe_3O_4 Nanoparticles) appeared, as it was diagnosed initially by approaching a magnet from the container beaker on the resulting oxide, we would notice the attraction of the precipitate to it.
4- The precipitate formed was withdrawn using a magnet and washed several times using distilled water until the washing water became neutral.
5- The formed precipitate was separated from the filtrate by using filter paper with small pores, and then the resulting precipitate was dried by placing in an oven at 50°C for 4 hours.
6- Then the sample was examined with a scanning electron microscope (SEM) to see the size of the nanoparticles.

3g of Nano iron particles were deposited on the cylindrical polypropylene water filter and each layer of the filter has pores with diameter of around 1 micron, and the container was equipped valves that allow water to enter from one side and exit from the other side of the container.

RESULT AND DISCUSSION

Diagnostic of nanoparticles in a SEM, EDX AND XRD.

The results of the scanning electron microscope (SEM) analysis of iron nanoparticles showed that their sizes ranged approximately about 85.5 nm, as shown in Figure (2).

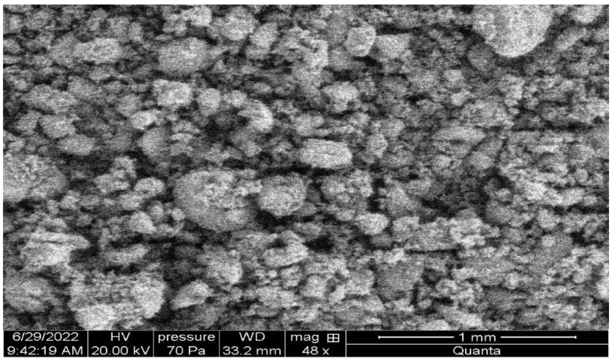
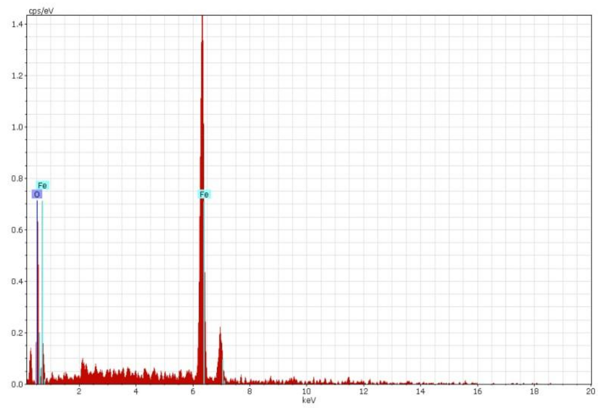


Figure 2: Shape and sizes of Iron Nanoparticles under a scanning electron microscope (SEM)

Figure (3) explained Energy-dispersive X-ray spectroscopy (EDX), which is important in analyzing the elements in order to know the chemical properties of the sample, which proved the presence of Iron nanoparticles, the EDX spectra of the synthesized material showing the peaks of Fe and O_2 in good elemental composition with no additional peak of any pollution.



Spectrum: Acquisition

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Oxygen	K-series	13.26	23.36	51.54	3.82
Iron	K-series	43.51	76.64	48.46	1.65
	Total:	56.77	100.00	100.00	

Figure 3: Energy-dispersive X-ray (EDX) spectroscopy of Iron nanoparticles

The manufacture of the synthesized silver nanoparticles was more supported by X-ray diffraction (XRD). The figure (4) showed six distinct diffraction peaks at 2θ values: 30.1, 35.5, 43.2, 53.7, 57.3 and 62.8 which corresponded to 220, 311, 400, 422, 511 and 440 respectively, from the Standard Scheme for XRD spectroscopy of Iron nanoparticles (JCPDS silver: 19-629).

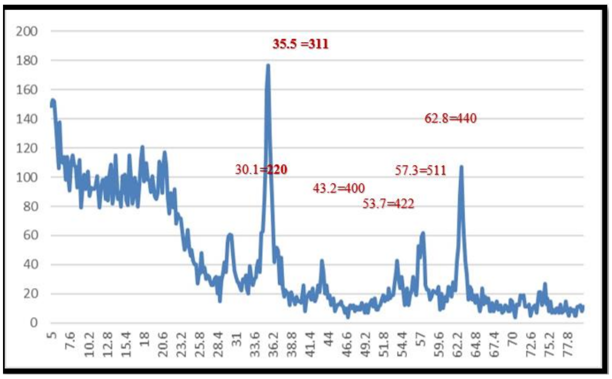


Figure 4: XRD spectrometry of the Iron nanoparticles

The results in Figure 5 indicate the apparent effectiveness of Fe_3O_4-NPs versus sand filter in removing TDS and SO_4 from water, as their concentrations in water before treatment were 1890 and 3146 mg/L, respectively. The Fe_3O_4-NPs achieved the largest TDS removal rate of 76.2%, as the TDS concentration in water decreased from 1890 to 450 mg/L, and the percentage for SO_4 removal was 64%, as the SO_4 concentration decreased from 3146 mg/L before treatment to 1125 mg/L after treatment.

As for the sand filter, the removal percentage of TDS was 3.7%, as the concentration of TDS decreased from 1890 mg/l to 1820 mg/l. The percentage of SO_4 removal was 5.3% as its concentration decreased from 3146 mg/L to 2980 mg/L after treatment.

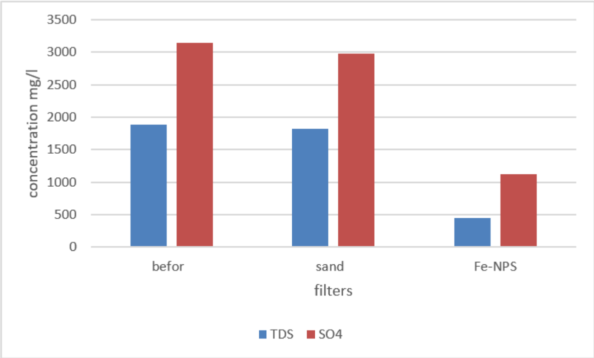


Figure:5 Mean values of TDS and SO_4 mg/l in water

Figure 5: Mean values of TDS and SO_4 (in mg/l) in water before and after treatment

The results in (Figure 6) clearly indicate the effectiveness of Fe_3O_4-NPs in removing bicarbonate, as it achieved a removal rate of 87.5%, as its concentration decreased from 32 mg/l before treatment to 4 mg/l after treatment .

As for the sand filter, the percentage of bicarbonate removal was 50%, as its concentration decreased from 32 mg/l before treatment to 16 mg/l after treatment.

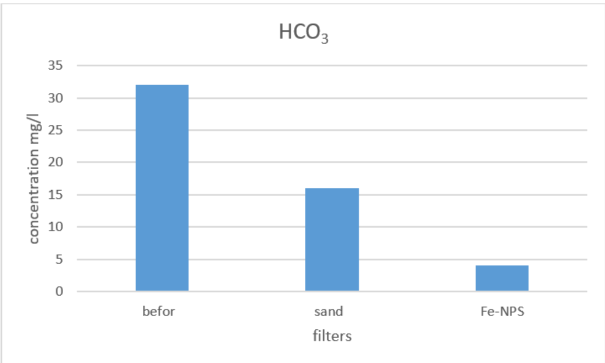


Figure 6: Mean values of HCO_3 mg/l in water before and after treatment

The effectiveness of Fe_3O_4-NPs was evident in removing chloride from water, as it achieved a clear removal rate of 82.8%, as the chlorine concentration decreased from 725 mg/l before treatment to 125 mg/l after treatment.

As for the sand filter, the removal rate of chloride was very low (i.e. 3.5%), as the chloride concentration decreased from 725 mg/l before treatment to 700 mg/l after treatment (Figure 6).

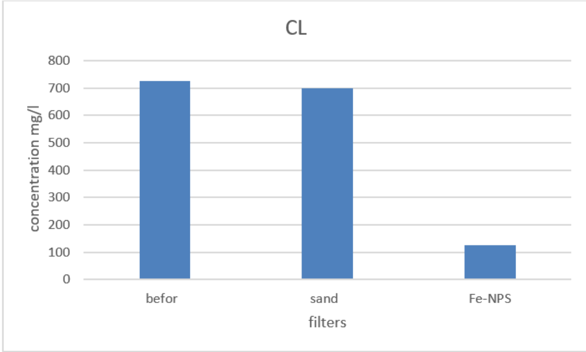


Figure 7: Mean values of Cl (mg/l) in water before and after treatment

The mechanics of iron nanoparticles in removing pollutants from water can be made in several ways, including: electrostatic interaction between pollutants and magnetic nanomaterials due to the availability of different biomolecules on the surfaces of magnetic nanoparticles, chemical diffusion between adsorbents and adsorbents, surface deposition, redox reactions, and ion exchange due to the presence of groups Functional hydroxyl OH, the composition of the bonding ions, and the bonding on the surfaces [20]. Due to many features such as surface modifiability by different materials and functional groups, iron-based nanoparticles are usually used to remove a specific contaminant together as a combination of physical and chemical adsorption, reduction, precipitation, and purification [16].

CONCLUSION & RECOMMENDATION

Nano iron oxide (Fe3O4-NPs) proved to be highly effective in removing pollutants from water, it achieved high removal rates of 76.25% for TDS but sand filter has a low removal rate of 3.7%. The percentage of SO_4 removal by nano iron oxide was 64% while in sand filter the removal rate was 5.3%. Further, iron oxide nanoparticles removed HCO_3 and Cl, with the removal rates reaching 87.5% and 82.8% respectively. However, the removal efficiency of filter sand was 50% and 3.5% for HCO_3 and Cl, respectively.

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