

ABSTRACT

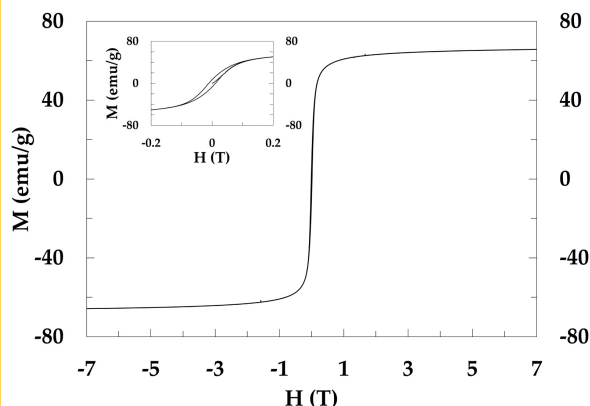
CO₂-foams show significant potential for improving mobility control in CO₂ Enhanced Oil Recovery (EOR) processes and for the geological carbon sequestration. The addition of nanoparticles (NPs), such as Fe₃O₄, has been shown to enhance the stability of these foams, especially when used in conjunction with surfactants. Apart from their role in stabilization, Fe₃O₄ NPs possess distinctive magnetic properties, making them useful in various applications. In this study, we explore the novel application of these nanoparticles, initially intended for stabilizing CO₂-foams, as tracers for monitoring the migration of subsurface CO₂ plumes. This monitoring is envisioned through the detection of small quantities of these particles within subsurface fluid environments. To facilitate this, we use an Induction Heating (IH) technique, involving exposing a solution with small amounts of Fe₃O₄ NPs to a high-frequency alternating magnetic field, then measuring the resulting temperature changes using an infrared camera variations. The results indicate a direct correlation between the NP concentration and the observed temperature increase in the solution.

MATERIALS

- Characterization of the nanoparticles involved the use of Dynamic Light Scattering (DLS), Transition Electron Microscopy (TEM), and Vibrating-Sample Magnetometry (VSM).
- The following properties were characterized for both nanoparticles:
 - Mean hydrodynamic diameter
 - Zeta potential
 - Average particle size
 - Magnetization curves

Physical properties of nanoparticles

Nanoparticle	Mean hydrodynamic diameter in DI water (nm)	Zeta potential (mV)	Average particle size (TEM)(nm)	Saturation magnetization (emu/g)	Coercivity (Oe)
98 % Fe ₃ O ₄	502.9	-34.56	100	65.6	104.3

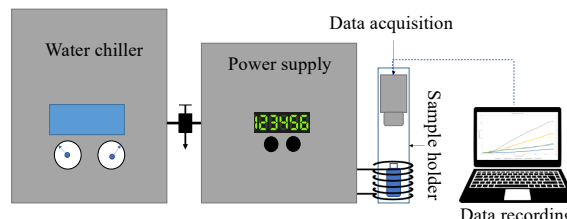


Magnetization curve obtained from VMS

METHODS

Induction Heating Method

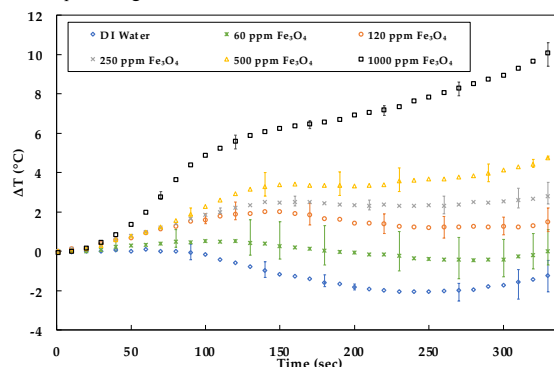
A heating effect is observed once solutions carrying magnetic NPs are exposed to alternating magnetic fields [1]. Such nanoparticles, including Fe₃O₄ NPs, find diverse applications, notably in targeted hyperthermia treatment within the medical field [2]. In magnetic nanofluids, which are colloidal suspensions of these nanoparticles in a carrier fluid, the heat generation results from a combination of hysteresis loss and Neel and Brownian relaxations. These effects vary based on the size and composition of the nanoparticles [3]. To investigate this phenomenon further and establish the relationship between the concentration of nanoparticles and the corresponding increase in temperature (ΔT), we have developed an experimental setup, comprising an induction heater as the power source, a custom-made induction coil, a sample holder, and a digital thermal camera for precise measurement and recording of temperature changes.



Experimental setup of Induction Heating Method

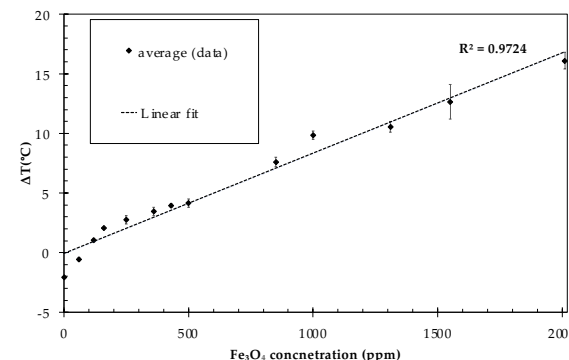
RESULTS

Fe₃O₄ NP suspensions in deionized (DI) water at concentrations of 60, 120, 250, 500, and 1000 ppm were prepared. The sample were sonicated to ensure uniformity, were subjected to the same magnetic field for the same duration at room temperature, and the resulting temperature changes (ΔT) were recorded. For analytical consistency, initial temperature readings were extracted from all the curves. The findings revealed a general upward trend in heat generation for all samples, with those containing higher concentrations of magnetic particles producing more heat.



ΔT vs. time for different nanoparticle solutions

Examining the relationship between ΔT and varying concentrations of NPs reveals the interplay between these factors. A linear regression analysis, based on 13 data points, resulted in an R^2 value of ~ 0.97 , indicating a strong correlation. The figure below graphically represents this relationship.



Temperature change versus concentrations of nanoparticles.

CONCLUSIONS

- ΔT values were obtained across a wide range of NP concentrations under same applied magnetic field.
- The obtained ΔT values were plotted against the corresponding NP concentrations, revealing a linear relationship between the two.
- The observed linear relationship exhibited a high degree of correlation with an R^2 value of 0.97.
- The sensitivity of this method was determined to be 120 ppm.

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ACKNOWLEDGEMENTS

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