IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, October 2024

Effect of Nanoparticle Surface Design on Blood Retention and Elimination Dynamics in Vivo

Mukesh Kumar Yadav[1] and Dr. Versha Gupta[2]
Research Scholar, Department of Chemistry[1]
Assistant Professor, Department of Chemistry[2]
Sunrise University, Alwar, Rajasthan, India

Abstract: *A variety of biocompatible materials, including poly dextran and polyvinylpyrrolidone have been used to modify the magnetic nanoparticles with a core diameter of 10 nm that are stabilized by sodium oleate and bovine serum albumin in phosphate buffer. Scanning electron microscopy and the dynamic light scattering technique were used to analyze prepared biocompatible magnetic fluids and determine the particle size distribution. Biocompatible substances were injected into the mice's bloodstreams to investigate the removal of various modified magnetic nanoparticles from the bloodstream. Additional blood samples were collected at certain intervals. The SQUID magnetometer was used to measure the magnetic moment of the lyophilized blood samples. The time-dependent magnetic moment of magnetic nanoparticles and those modified by DEX, PEG, and PVP normalized to Fe3O4 demonstrated that the time it takes for magnetic nanoparticles to circulate in the bloodstream is dependent on the modification material. While magnetic nanoparticles modified by DEX, PEG, and PVP circulated in the circulation for up to three hours, the unmodified magnetic nanoparticles were retained by the reticuloendothelial system after one hour.*

Keywords: The in vivo elimination of magnetic nanoparticles the bloodstream modifications, biodistribution, circulation

I. INTRODUCTION

Magnetic nanoparticles have garnered a lot of attention lately because of their ferro- and superparamagnetic qualities, which are advantageous for both engineering and medicine. Specifically, magnetic fluids (MF), which are composed of magnetic nanoparticles and a liquid carrier, are used as contrast agents in magnetic resonance imaging [1, 2], as mediators in the treatment of cancer by magnetic hyperthermia [3], and several other applications. Because of their size (about 10 nm), magnetic nanoparticles have the significant benefit of being able to pass through biological membranes [4]. This makes it possible to actively use nanoparticles as drug delivery vehicles. MNPs coated with biocompatible polymers are often used in both in vitro and in vivo studies [5]. Depending on the bilayer's characteristics and particle size, these systems may evade the body's natural defense mechanisms and stay in the circulation for a considerable amount of time [6]. Chemotherapy's systemic toxicity cannot be decreased, as is well known [7], which results in inadequate effect and suboptimal dosage. By raising the medication concentration in the tumor, therapy that employs a targeted drug delivery strategy may improve the therapeutic efficacy [8]. Particle bioavailability and in vivo uses are limited because nanoparticles are often eliminated by the reticuloendothelial system (RES), namely by the liver's Kupffer cells [9]. Our objective was to alter the surface of magnetic particles using suitable biocompatible substances that would reduce RES clearance and increase particle circulation time.

II. EXPERIMENTAL

Materials

Sigma Aldrich supplied bovine serum albumin, dextran with an average molecular weight (Mw) of 70 000, and poly(ethylene glycol) with an average Mw of 1000. Fluka provided the average Mw 40 000 of polyvinylpyrrolidone K30, whereas Riedel-de Han provided sodium oleate (C17H33COONa). Ammonium hydroxide (NH4OH), ferrous sulphate heptahydrate (FeSO4•7H2O), and ferric chloride hexahydrate (FeCl3•6H2O) were often used in magnetite production.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, October 2024

Animals

The mice used in the experiment were males, weighing 24.6±1.4 g. They were kept separately in cages with a 12-hour artificial light/dark cycle. Mice were given unlimited access to MP-OS06 (BIOFET, SR) food and water. Mice were put in a desiccator filled with diethyl ether (which caused mild anesthesia when inhaled) prior to blood collection.

Sample preparation and experimental details

MNPs were made using the co-precipitation technique with a 2:1 molar ratio of ferric and ferrous salts. A black precipitate appeared instantly when the ammonium hydroxide solution was introduced to the flask containing the water solution of Fe3+ and Fe2+ and magnetite while being vigorously stirred. Following washing, the particles were separated from the water and, in order to stop them from clumping together, sodium oleate was added at 50 °C. The suspension was then brought to a boil by heating it up. Centrifugation at 9000 rpm for 30 minutes was then used to eliminate any unwanted agglomerates that had formed during this procedure (Hettich universal 32, Germany). In order to enhance the biocompatibility of magnetic particles, bovine serum albumin (BSA) was modified with a weight ratio of BSA/Fe3O4 = 2. The mixture was incubated for six hours at 200 rpm and 40 °C in a horizontal shaker (Heidolph Promax 1020). Phosphate buffer was then used to bring the colloid's pH down to 7.4. Moreover, MFBSA is the term used to describe the final sample, which is made up of magnetic fluid that has been altered by BSA. After that, MFBSA was combined with water solutions of DEX (MFBSADEX), PEG (MFBSAPEG), and PVP (MFBSAPVP), and it was incubated for 24 hours at 40 °C and 200 rpm on a horizontal shaker. The DEX/magnetite weight ratio was 3, although the PEG/magnetite and PVP/magnetite weight ratios were also 0.25.

Transmission electron microscopy (TEM, Tesla BS 500 microscope, operating at 90 kV with 80 000 magnification) and scanning electron microscopy (SEM, JEOL 7000F microscope) were used to examine the size and morphology of all generated MF samples. Using the dynamic light scattering (DLS) technology (Zetasizer NanoZS, Malvern, UK), which gauges the Brownian motion velocity of particles, the particle size distribution was determined. Zeta potential was measured using laser Doppler velocity to investigate the materials' stability. The SQUID magnetometer (Quantum Design MPMS 5XL) was used to measure the magnetic moment. Both the manufactured biocompatible samples and the unmodified MF were diluted in water for injections (1:1) and given intravenously to the tail vein of mice in order to investigate the removal of various surface modified MNPs from the circulation. After 15 minutes, 30 minutes, 1, 2, 3, 4, 5, and 24 hours, respectively, the blood was drawn. Following lyophilization, the blood was frozen, and the samples' magnetic moment was measured at room temperature.

III. RESULTS AND DISCUSSION

TEM measurements of the unaltered MF revealed that the mean core diameter of the magnetic particles was 10 nm (Fig. 1a). The approximate spherical form of the nanoparticles was verified by SEM studies, and Table I summarizes the average MFs diameters. The existence of biocompatible shells is shown by the increase in the hydrodynamic diameter of modified magnetic nanoparticles relative to the diameter of unmodified magnetic particles, as shown in Table I and Figs. 1b–d. DLS is an additional method for determining the particle size distribution. Results of the z-average hydrodynamic diameters of all examined are shown in Table I.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, October 2024

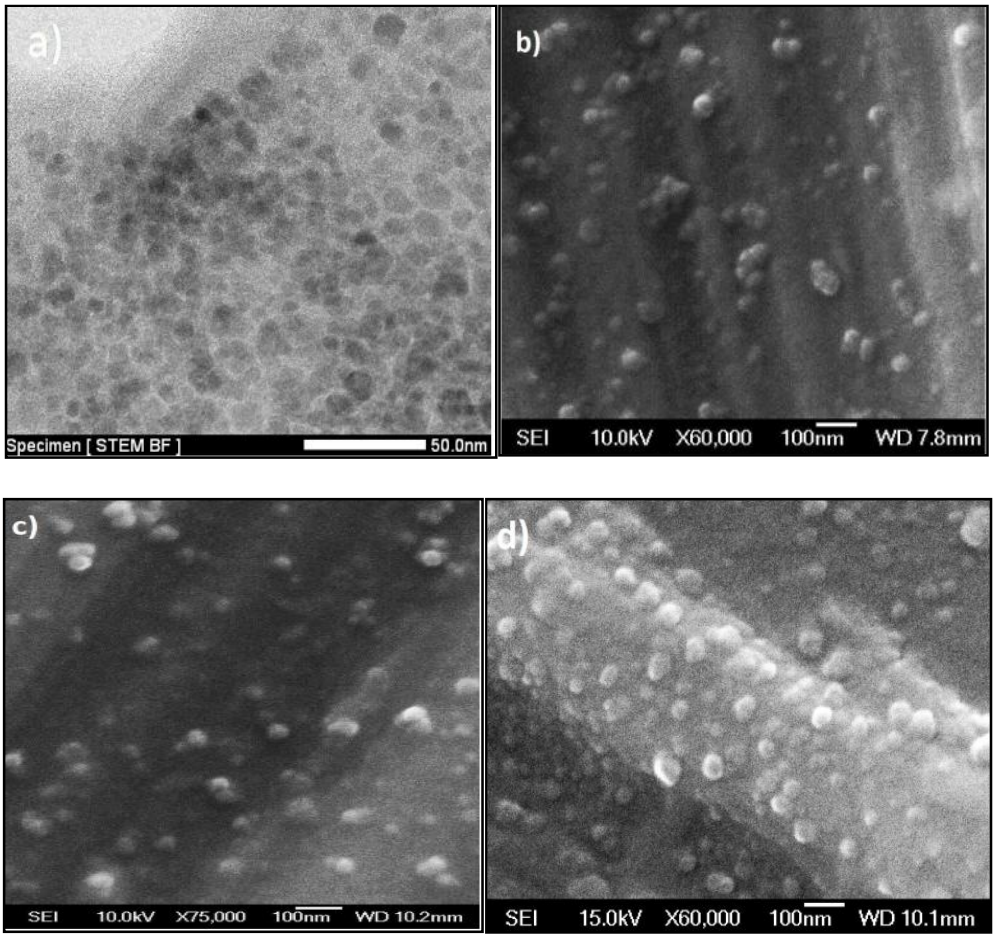

Fig. 1. (a) TEM image of magnetic nanoparticles in MF; SEM image (b) MFBSAPEG, (c) MFBSAPVP, (d) MFBSADEX.

TABLE :1. I Comparison of the MNP diameters and Zeta potentials (ZP) of prepared MFs obtained by SEM and DLS.

Method	MFBSA	+ PEG	+ PVP	+ DEX
DSEM [nm]	28	29	34	33
DDLS [nm]	53	63	59	69
ZP [mV]	- 19	- 39	- 49.8	- 47

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, October 2024

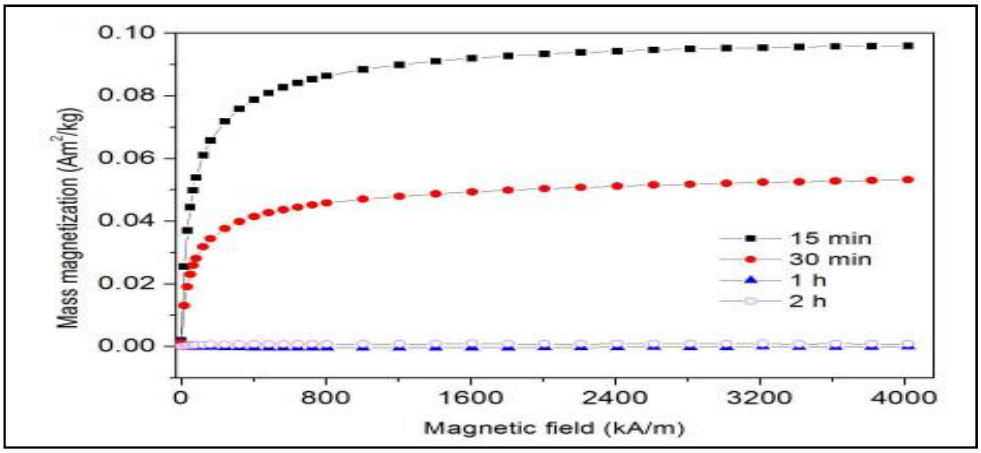

Fig. 2. Magnetization curves of MFBSA.

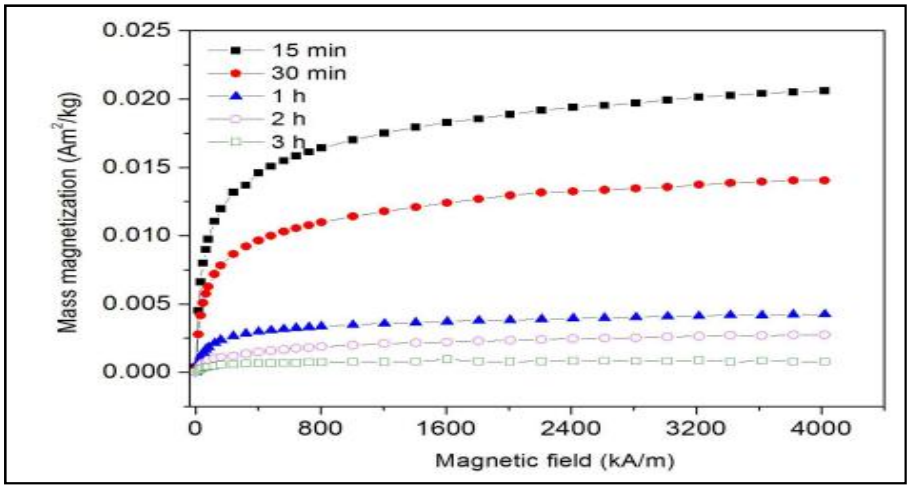

Fig. 3. Magnetization curves of MFBSAPEG.

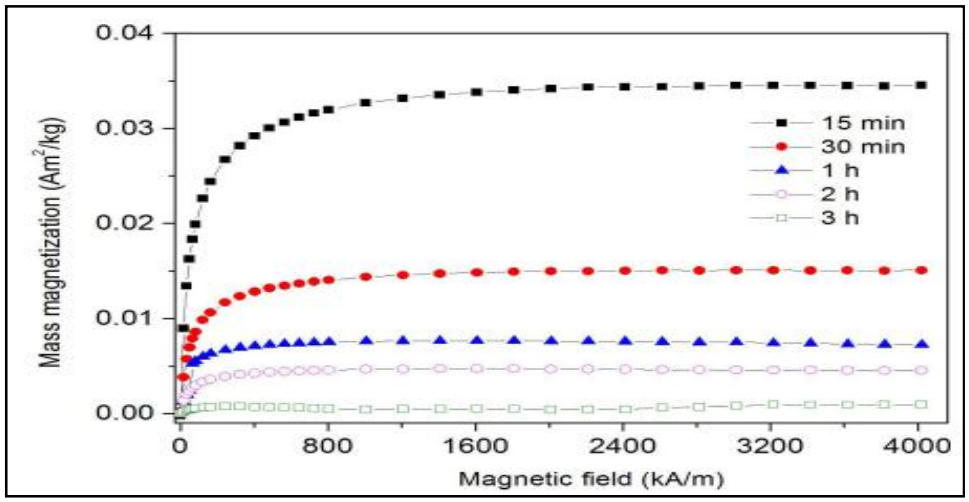

Fig. 4. Magnetization curves of MFBSAPVP.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, October 2024

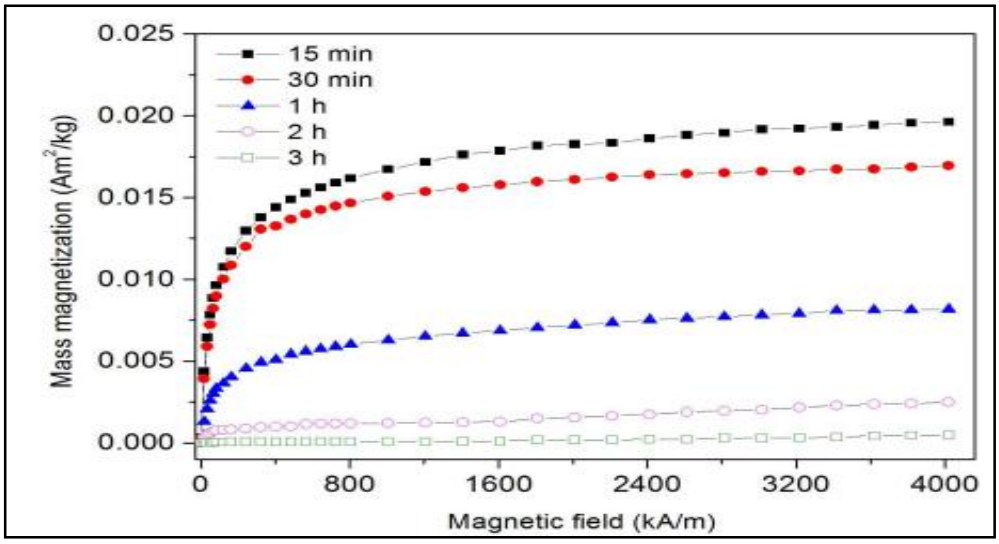

Fig. 5. Magnetization curves of MFBSADEX.

MFBSA, MFBSADEX, MFBSAPEG, and MFBSAPVP samples. Compared to SEM measurements, these values are greater. This fact may be explained by using a variety of methods based on distinct ideas. The findings of the Zeta potential test showed that the MFs under study had high colloidal stability. MFBSA modified by PEG, PVP, and DEX had a magnetite concentration of 0.492 mg Fe3O4/mouse, while MFBSA utilized for intravenous administration had a concentration of 1.025 mg Fe3O4/mouse.

The magnetization curves of the lyophilized blood containing MFBSA (Fig. 2), MFBSA modified by PEG (Fig. 3), PVP (Fig. 4), and DEX (Fig. 5) are shown in the following figures. The temporal dependence of magnetic moments for both modified and unmodified magnetic particles in dried blood samples adjusted to the Fe3O4 weight is shown in Figure 6.

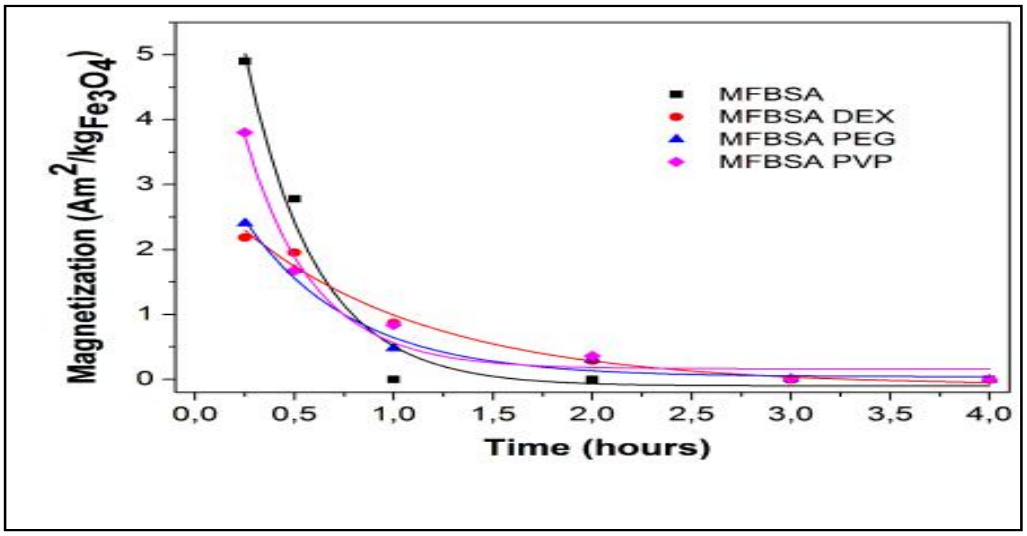

Fig. 6. Time dependence of magnetization of different modified MNPs in bloodstream.

Elimination of Magnetic Nanoparticles

Over time, the nanoparticles' magnetism declined in all samples. One hour after treatment, the magnetization of unmodified MNPs in dried blood samples decreased to zero. Even three hours later, the magnetism of the DEX, PEG,

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.57
Volume 4, Issue 1, October 2024

and PVP-modified magnetic particles was greater than zero. The data collected demonstrated that the material utilized for modification affects how long MFBSA circulates in the bloodstream.

IV. CONCLUSIONS

It was investigated how surface modification of magnetic nanoparticles affected the bloodstream's circulation time. In contrast to MNPs modified by DEX, PEG, and PVP nanoparticles, which remained in the circulation for up to three hours, the acquired data demonstrated that all MNPs of MFBSA were caught by the reticuloendothelial system within one hour. Surface changes for nanoparticles increased their circulation time and reduced their RES clearance. Given the significance of this characteristic for the effectiveness of in vivo targeting, further research on the alterations of various nanoparticles is necessary.

REFERENCES

[1]. R. Weissleder, A. Bogdanov, E.A. Neuwelt, M. Papisov, Adv. Drug Deliv. Rev. 16, 321 (1995).
[2]. C. Sun, J.S.H. Lee, M. Zhang, Adv. Drug Deliv. Rev. 60, 1252 (2008).
[3]. C.C. Berry, J. Phys. D Appl. Phys. 42, 224003 (2009).
[4]. G.M. Whitesides, Nat. Biotechnol. 21, 1161 (2003).
[5]. M. Chanana, Z. Mao, D. Wang, J. Biomed. Nanotechnol. 5, 652 (2009).
[6]. S. Stolnik, L. Illum, S. Davis, Adv. Drug Deliv. Rev. 16, 195 (1995).
[7]. H. Nasser, in: Holland-Frei Cancer Medicine - 6, Eds. D.W. Kufe, D.W. Kufe, R.E. Pollock, R.R. Weichselbaum, R.C. Bast, Jr, T.S. Gansler, J.F. Holland, E. Frei, BC Decker, Hamilton (ON) 2003, Ch. 13.
[8]. V. Zavisova, M. Koneracká, M. Múčková, J. Lazová, A. Juríková, G. Lancz, N. Tomašovičová, M. Timko, J. Kováč, I. Vávra, M. Fabián, A.V. Feoktystov, V.M. Garamus, M.V. Avdeev, P. Kopčanský, J. Magn. Magn. Mater. 323, 1408 (2011).
[9]. Liu Li, T.K. Hitchens, Qing Ye, Yijen Wu, B. Barbe, D.E. Prior, W.F. Li, Fang-Cheng Yeh, L.M. Foley, D.J. Bain, Chien Ho, Biochim. Biophys. Acta 1830, 3447 (2013).