International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(REVIEW ARTICLE)

Nanotechnology: Current trends in detections of microbial pathogens

Maria Adewole *

Department of Microbiology, Faculty of Science, Oduduwa University, Nigeria.

International Journal of Science and Research Archive, 2023, 10(02), 1173–1178

Publication history: Received on 14 November 2023; revised on 27 December 2023; accepted on 30 December 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.10.2.1085

Abstract

The circulation of pathogens in developing countries is one of the major causes of infectious disease outbreaks. Currently, there are limitations to already existing methods for microbial pathogen detection. A significant number of pathogens are left undetected via of conventional methods. The detection methods that are innovative, rapid with high sensitivity and specificity are required to target pathogens. This will aid to overcome present drawbacks in disease management. Nanotechnology is a recent advancements leading to the development of nanoparticle-based assay for detection of specific pathogens. Gold nanoparticles are known to have unique and high surface area. This makes them an ideal candidate for pathogen specific detection. The gold nanoparticles have unique physicochemical properties which are more advantageous over existing conventional detection methods. This review focused on the application of nanotechnology in microbial pathogen detection. With an insight on the exploration of nanotechnology to overcome the limitation of existing detection methods.

Keywords: Nanotechnology; Microbial pathogens; Detection methods; Nanoparticles

1. Introduction

Microorganisms are well known ubiquitous, imperceptible and small creatures. They are numerous groups of microorganisms which can be pathogenic and non-pathogenic microorganisms. Pathogens are life forms that causes varied health conditions [1]. Our bodies are normally full of organisms which can be destructive or safe (advantageous), in any case, a few organisms as it were cause issue in the event that our resistant framework is debilitated or on the off chance that they oversee to enter a ordinarily sterile portion of our body.

A pathogen is a living being that causes illness. The body is normally full of organisms. Pathogens are diverse and can cause infection upon entering the body. All a pathogen has to thrive and survive could be a have. Once the pathogen sets itself up in a host's body, it oversees to maintain a strategic distance from the body's safe reactions and employments the body's assets to reproduce before exiting and spreading to a modern have [2]. Pathogens can be transmitted a couple of ways depending on the sort. They can be spread through skin contact, real liquids, airborne.

Pathogens are distinctive and can cause infection upon entering the body. A pathogen should flourish and survive a have, once the pathogen set itself up in a host's body, it safe reactions and employments the body the body's reaction to reproduce some time recently existing spreading into a modern have. Pathogens can be transmitted few ways depending on the sorts. They can be spread skin contact, body liquids, airborne particles, contact with feaces and touching surfaces touched by a contaminated individual [3]. Whereas numerous organisms are safe to people, others can cause genuine issues. They can ruin nourishment, present poisons, causes infections and leads to a have of other issues. But with the evolvement and inclusion of innovation, Nanotechnology has incredibly contributed to the determination of infections owing to the quick nature and tall sensitivity [4].

* Corresponding author: Maria Adewole

This paper aims to investigate the current trends in microbial detection of pathogens using nanotechnology.

2. Nanotechnology and Microbial Pathogens

In common, nanoparticles utilized within the field of biotechnology run in molecule measure between 10 and 500 nm, at times surpassing 700 nm. The nanosize of these particles permits different communications with biomolecules on the cell surfaces and inside the cells in way that can be decoded and assigned to different biochemical and physiochemical properties of these cells [5]. Essentially, its potential application in medicate conveyance framework and noninvasive imaging advertised different focal points over customary pharmaceutical agents. In an exertion to utilize nanoparticles at their full throttle, it is imperative that the nanoparticulate frameworks ought to be steady, biocompatible, and specifically coordinated to particular locales within the body after systemic organization. More particular focusing on frameworks are planned to recognize the focused on cells such as cancer cells [6]. This could be accomplished by conjugating the nanoparticle with an suitable ligand, which incorporates a particular official action with regard to the target cells. In expansion, nanoparticles give astage to join numerous duplicates of helpful substance on it and thus increment the concentration of restorative and demonstrative substances at the neurotic location [7]. Too, the concentration and flow of the dynamic atom can be changed by controlling the molecule estimate of nanoparticles (>3–5 nm). This control in molecule measure in conjugation with surface coating with stealth ligand permits them to cloak against body's safe framework, empowering them to circulate within the blood for longer period of time. These progresses within the field of biotechnology have opened an unending openings for atomic diagnostics and therapy. Once focused on (dynamic or detached), these nanocarriers can be planned in a way to encourage them to act as imaging tests utilizing assortment to techniques such as ultrasound (US), X-ray, computed tomography (CT), positron emanation tomography (PET), attractive reverberation imaging (MRI), optical imaging, and surface-enhanced Raman imaging (SERS) [8]. These so-called "molecular imaging probes" can noninvasively give profitable data around separate variations from the norm in different body structures and organs to determine the extent of illness, and assess the adequacy of treatment. Thus brief atomic imaging empowers the visualization of the cellular work and the follow-up of the atomic structure with distortion to the cellular structure [9].

Over the year's nanoparticles such as attractive nanoparticles (press oxide), gold and silver nanoparticles, nanoshells, and nanocages have been persistently utilized and adjusted to empower their utilize as a demonstrative and helpful agent.

3. Gold Nanoparticles

Colloidal gold, too known as gold nanoparticles, may be a suspension (or colloid) of nanometer-sized particles of gold. The history of these colloidal arrangements dates back to Roman times when they were utilized to recolor glass for embellishing purposes [10]. In any case, the present day logical assessment of colloidal gold did not start until Michael Faraday's work of the 1850s, when he watched that the colloidal gold arrangements have properties that contrast from the bulk gold. Thus the colloidal arrangement is either an strongly ruddy color (for particles less than 100 nm) or a grimy yellowish color (for bigger particles). These interesting optical properties of these gold nanoparticles are due to their special interaction with light. Within the nearness of the wavering electromagnetic field of the light, the free electrons of the metal nanoparticles experience an wavering with regard to the metal lattice [11]. This prepare is thunderous at a specific recurrence of the light and is named the localized surface plasmon reverberation (LSPR). After assimilation, the surface plasmon rots radiatively coming about in light diffusing or nonradiatively by changing over the ingested light into warm. In this way for gold nanospheres with molecule measure around 10 nm in distance across have a solid assimilation maximum around 520 nm in fluid arrangement due to their LSPR. These n

Gold nanorods (NRs) with tunable optical assimilations at unmistakable and near-infrared wavelengths; a) Optical retention spectra of gold NRs with distinctive angle ratios (a–e); b) Color wheel, with reference to gold NRs labeled a–e. TR, transverse [12].

Besides, the properties and applications of colloidal gold nanoparticles moreover depend upon its shape. For case, the rod-shaped nanoparticles have two resonances: one due to plasmon swaying along the nanorod brief hub and another due to plasmon swaying along the long hub, which depends emphatically on the nanorod perspective proportion, that's , length-to-width proportion [13]. When the nanorod angle proportion is expanded, the long-axis LSPR wavelength position ruddy shifts from the unmistakable to the NIR conjointly dynamically increments in oscillator quality For case, rodlike particles have both transverse and longitudinal retention crest, and anisotropy of the shape influences their self-assembly.Due to these special optical properties, gold nanoparticles are the subject of considerable investigate, with gigantic applications counting natural imaging, hardware, and materials science. In this way to create gold nanoparticles

for particular applications, dependable and high-yielding strategies counting those with circular and nonspherical shapes have been created over the period of years [14]. This method uses the chemical decrease of gold salts such as hydrogen tetrachloroaurate (HAuCl4) utilizing citrate as the lessening specialist. This method produces monodisperse round gold nanoparticles within the extend of 10–20 nm in distance across. Be that as it may, the blend of bigger gold nanoparticles with distances across between 30 and 100 nm was detailed by Brown and Natan through seeding of Au3+ by hydroxylamine [15]. Consequent inquire about driven to the adjustment of the shape of these gold nanoparticles coming about in bar, triangular, polygonal bars, and circular particles. These following gold nanoparticles have special properties, giving a tall surface region to volume proportion. Besides, the gold surface offers a special opportunity to conjugate ligands such as oligonucleotides, proteins, and antibodies containing useful bunches such as thiols, mercaptans, phosphines, and amines, which illustrates a solid partiality for gold surface [16 -25]. The realization of such gold nanoconjugates coupled with emphatically upgraded LSPR gold nanoparticles have found applications in less complex but much capable imaging procedures such as dark-field imaging, SERS, and optical imaging for the determination of different infection states [26].

There is a built up of gold nanoparticles for cancer imaging by specifically transporting AuNPs into the cancer cell core. In arrange to specifically transport the AuNPs into the cancer cell core, they conjugated arginine–glycine–aspartic corrosive peptide (RGD) and a atomic localization flag peptide (NLS) to a 30-nm AuNPs by means of PEG. RGD is known to target αvβ6 integrins receptors on the surface of the cell, while NLS grouping lysine–lysine–lysine–arginine–lysine (KKKRK) grouping is known to relate with karyopherins (importins) within the cytoplasm, which empowers the translocation to the nucleus. Thus the nearness of RGD will empower cancer-cell-specific focusing on, while the nearness of NLS will show cancer cell core particular focusing on. This naturally created molecule was at that point focused on to human verbal squamous cell carcinoma (HSC) having αvβ6 integrins overexpressed on the cell surface (cancer demonstrate), and human keratinocytes (HaCat) (control) [27 -31]. The creators assist illustrated that RGD-AuNPs particularly target the cytoplasm of cancer cells over that of ordinary cells, and the RGD/NLS-AuNPs particularly target the cores of cancer cells over those of typical cells.

Similarly, detailed improvement of tumor-targeted gold nanoparticles as a test for Raman diffuses in vivo. These gold nanoparticles were encoded with a Raman reporter and encourage typified with a thiol-modified PEG coat. Furthermore, to particularly target tumor cells, the pegylated gold nanoparticles were at that point conjugated with an antibody against epidermal development figure receptor, which is some of the time overexpressed in certain sorts of cancer cells [32]. The Raman upgrade from these custom-made particles was at that point watched with electronic moves at 633 or 785 nm through SERS. The comes about gotten by Qian and colleagues propose the highly particular acknowledgment and location of human cancer cells, as well as dynamic focusing on of EGFR-positive tumor xenografts in creature models can be made utilizing SERS [33].

Besides, the utilize of gold nanorods as photothermal specialists sets them separated from all nanoprobes. Photothermal treatment (PTT) may be a method in which a photosensitizer is energized with particular band light (primarily IR). This enactment brings the sensitizer to an energized state where it at that point discharges vibrational vitality within the shape of warm. The warm is the genuine strategy of treatment that slaughters the focused on cells [34 -36]. One of the greatest later victories in photothermal treatment is the utilize of gold nanoparticles. Round gold nanoparticles absorptions have not been ideal for in vivo applications. This is often since the top retentions have been restricted to 520 nm for 10 nm distance across. In addition, skin, tissues, and hemoglobin have a transmission window from 650 up to 900 nm. Thus, for the rod-shaped gold nanoparticles with the assimilation within the IR locale, when specifically gathered in tumors when washed in laser light (within the IR locale), the encompassing tissue is scarcely warmed, but the nanorods change over light to warm, murdering the threatening cells [37]. This potential application of gold nanorods blesses them from other nanoprobes. In any case, their contradiction with other high-resolution imaging procedures such as MRI and irreproducibility in shapes driven to the innovation of nanocages and nanoshells.

Nanotechnology, the control and fabricate of materials and gadgets on the scale of molecules or little bunches of particles. The “nanoscale” is regularly measured in nanometres, or billionths of a meter (nanos, the Greek word for “dwarf,” being the source of the prefix), and materials built at this scale regularly show unmistakable physical and chemical properties due to quantum mechanical impacts [38 – 41]. In spite of the fact that usable gadgets this small may be decades absent (see microelectromechanical framework), strategies for working at the nanoscale have ended up basic to electronic designing, and nanoengineered materials have started to seem in buyer items. For case, billions of minuscule “nanowhiskers,” each about 10 nanometres in length, have been molecularly snared onto normal and manufactured strands to give recolor resistance to clothing and other textures; zinc oxide nanocrystals have been utilized to form undetectable sunscreens that square bright light; and silver nanocrystals have been implanted in gauzes to murder microbes and avoid contaminations Possibilities for long-standing time are various. Nanotechnology may make it conceivable to fabricate lighter, more grounded, and programmable materials that require less vitality to deliver

than customary materials, that deliver less squander than with ordinary fabricating, which guarantee more prominent fuel productivity in arrive transportation, ships, flying machine, and space vehicles [42]. Nanocoatings for both murky and translucent surfaces may render them safe to erosion, scratches, and radiation. Nanoscale electronic, attractive, and mechanical gadgets and frameworks with exceptional levels of data handling may be created, as may chemical, photochemical, and organic sensors for assurance, wellbeing care, fabricating, and the environment; modernphotoelectric materials that will empower the make of cost-efficient solar-energy boards; and molecular-semiconductor cross breed gadgets that will become engines for the following transformation within the data age [43 - 45]. The potential for enhancements in wellbeing, security, quality of life, and preservation of the environment are vast.

At the same time, noteworthy challenges must be overcome for the benefits of nanotechnology to be realized.

4. Conclusion

The review summarizes the world of micro biology and nanotechnology and how the existing field comes together to help mankind with the application in current detection of microbial pathogens.

References

[1] Badawi M, Ahmed M. Gold nanoparticles as high-resolution imaging contrast agents for early cancer diagnoses: computational study. International Journal of Chemistry and Applied Biological Sciences. 2014; 1(5):12.

[2] Ezeanya-Bakpa CC, Agbakoba NR, Aguigwe A, Ikuepamitan K. Comparison of Prevalence and Risk Factors for Methicillin-Resistant Staphylococcus aureus in Two Tertiary Institutions, Southern Nigeria. Sokoto Journal of Medical Laboratory Science. 2023; 8(3): 73-81.

[3] Bruins MR, Kapil S, Oehme FW. Microbial resistance to metals in the environment. Ecotoxicology Environment. 2000; 45(3):198–207.

[4] Veigas B, Machado D, Perdigão J, Portugal I, Couto I, Viveiros M, Baptista PV. Au-nanoprobes for detection of SNPs associated with antibiotic resistance in Mycobacterium tuberculosis. Nanotechnology. 2010, 21.

[5] Ezeanya-Bakpa CC, Agbakoba NR, Udeogu CV, Uduchi IO, Oguejiofor CB, Ekelozie, IS. Genital Mycoplasmas and Gynaecologic Cancer: A Systematic Review. African Journal of Clinical and Experimental Microbiology. 2023; 24(4): 339-347.

[6] Doria G, Conde J, Veigas B, Giestas L, Almeida C, Assunção M, Rosa J, Baptista PV. Noble Metal Nanoparticles for Biosensing Applications. Sensors. 2012; 12(2):1657-1687.

[7] Ezeanya-Bakpa CC, Agbakoba NR, Enweani-Nwokelo IB, Oguejiofor CB. Phylogeny-based identification of Mycoplasma genitalium in a Nigerian population of apparently healthy sexually active female students. Pan African Medical Journal. 2022; 41:71-76.

[8] Pierre P, Stefano V, Marianna R, Michael DD, Tuan T, Frank B, Martina N, Alessandro B, Alessandro P, Roberto C, Hanadi S, De Cola L. Responsive Nucleic Acid-Based Organosilica Nanoparticles. Journal of the American Chemical Society. 2023, 145 (42): 22896-22902.

[9] Ezeanya-Bakpa CC, Agbakoba NR, Oguejiofor CB, Enweani-Nwokelo IB. Sequence analysis reveals asymptomatic infection with Mycoplasma hominis and Ureaplasma urealyticum possibly leads to infertility in females: A cross-sectional study. International Journal of Reproductive Biomedicine. 2021; 19(11): 951-958.

[10] Qing Y, Wenzhe W, Haixia J, Luyao T, Mingjuan Y, Juan W, Xia L, Luqi H, Lanping G, Wenyuan G. Surface Membrane Coating as a Versatile Platform for Modifying Antitumor Nanoparticles. ACS Materials Letters. 2022; 4 (10): 2019-2050.

[11] Ezeanya-Bakpa CC, Adetunji CO, Enosabata IA, Olori E. Lycopene for wound infection: In vitro susceptibility of drug-resistant clinical pathogens. Tropical Journal of Natural Product Research. 2021; 5(1):49-52.

[12] Abiola ND, Sunil C, Luke SW, Patricia MG, Shani AMO, Zoe P, Nikolas JH. Quantification by Luminescence Tracking of Red Emissive Gold Nanoparticles in Cells. Journal of Advanced Chemical Sciences. 2021, 1 (2): 174-186.

[13] Akharaiyi FC, Ezeanya-Bakpa, CC, Otumala, SO. Inhibition of methicillin resistant Staphylococcus aureus (MRSA) with underutilized medicinal plants extracts. International Medical Journal. 2021; 28(6): 4953-4964.

[14] Piotr G, Moritz K, Michael G, Alberto G. Integrating Nanotechnology into Cancer Care. Academic Chemical Sciences in Nanotechnology. 2019; 13 (7): 7370-7376.

[15] Osuji A, Agbakoba NR, Ifeanyichukwu MO, Abdullahi IN, Ezeanya-Bakpa CC, Duru GC. Hepatitis B virus serological profile and associated risk factors in surface antigen negative blood donors in Nigeria. Microbes and Infectious Diseases. 2021; 2(3): 440-450.

[16] Ye K, Yi C, Min L, Guangyue Z, Yajie Z, Ye Z, Renjun P. Geometrical Confinement of Gadolinium Oxide Nanoparticles in Poly(ethylene glycol)/Arginylglycylaspartic Acid-Modified Mesoporous Carbon Nanospheres as an Enhanced T1 Magnetic Resonance Imaging Contrast Agent. ACS Applied Materials & Interfaces. 2018; 10 (31): 26099-26107.

[17] Nkwoemeka NE, Anyamene CO, Ezeanya-Bakpa CC, Okwelogu IS. Prevalence of Pulmonary Aspergillosis among HIV-positive subjects in a tertiary health-care institution, Nigeria. Pakistan Journal of Medical and Health Sciences. 2020; 14(4):1583-1587.

[18] Jiayingzi W, Yafei Z, Kejia J, Xiaoyu W, Nicholas TB, Jing Z, Shanshan J, Jing L, Peng H. Enzyme-Engineered Conjugated Polymer Nanoplatform for Activatable Companion Diagnostics and Multistage Augmented Synergistic Therapy. Advanced Materials. 2022, 34 (18): 200-234.

[19] Ehis-Eriakha CB, Ezeanya-Bakpa CC, Akemu SE, Yahaya SO. Assessment of indigenous Rhizospheric soil microbes from Zea mays and Manihot esculenta for Plant growth promoting traits. Archive of Science and Technology. 2020; 1: 88-97.

[20] Ting L, Hongguan W, Chongzhi Q, Bo B, Shuangliang Z, Honglai L. Nonnegligible nano-confinement effect on solvent-mediated interactions between nanoparticles. Chemical Engineering Science. 2022; 248: 117238.

[21] Ezeanya CC, Agbakoba NR, Enweani IB, Oguejiofor CB. Predominance of cervicitis agents with minimal testing rate within the student population in Benin City, Nigeria. Journal of Obstetrics and Gynaecology. 2019. 39(6):840-844.

[22] Mohammad YA, Huan Y, Tirusew T, Shuwen L, Son LH, Gang HL, Sung-Wook N, Yongmin C. Functionalized Lanthanide Oxide Nanoparticles for Tumor Targeting, Medical Imaging, and Therapy. Pharmaceutics. 2021; 13 (11):1890.

[23] Agbakoba NR, Adike CN, Enweani IB, Ezeanya CC, Akujobi CN. Molecular Detection of Mycoplasma pneumoniae Virulent Gene from Sputum Samples of Subjects Attending Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria. African Journal of Medicine and Medical Sciences. 2019; 48(2):225-231.

[24] Sidak M, Priya K, Arunima B, Ashutosh K, Takshashila T, Saurabh P, Deeksha T. Role of Microbial Nanotechnology in Diagnostics. Journal of Microbial Sciences. 2021, 237-274.

[25] Okoli AC, Agbakoba NR, Ezeanya CC, Oguejiofor CB, Anukam KC. Comparative Abundance and Functional Biomakers of the Vaginal and Gut Microbiome of Nigerian Women with Bacterial Vaginosis: A study with 16S rRNA Metagenomics. Journal of Medical Laboratory Science. 2019; 29(1):1-26.

[26] Eijaz AB, Nasreena S, Irfan R. Cosmetic and Medical Applications of Microbial Nanotechnology. Journal of Microbial Sciences. 2021, 321-342.

[27] Ejike CE, Agbakoba NR, Ezeanya CC, Anukam KC. Health, Social and Economic burden of Bacterial vaginosis among Nigerian women of child bearing age: Can Probiotics restore the vaginal dysbiosis? Journal of Medical Laboratory Science. 2019; 29(2):37-48.

[28] Elumalai K, Velmurugan S. Green synthesis, characterization and antimicrobial activities of zinc oxide nanoparticles from the leaf extract of Azadirachta indica (L.). Applied Surface Sciences. 2015; 345:329–336.

[29] Ejike CE, Agbakoba NR, Ezeanya CC, Emele FE, Oguejiofor CB, Dirisu J. Antifungal Susceptibility and Test for Cure of Candida Species among Vulvovaginal Candidiasis Patients in a Secondary care Hospital, Nigeria. African Journal of Clinical and Experimental Microbiology. 2018; 19(1):30-33.

[30] Gabrielyan L, Hakobyan L, Hovhannisyan A, Trchounian A. Effects of iron oxide (Fe3O4) nanoparticles on Escherichia coli antibiotic-resistant strains. Journal of Applied Microbiology. 2019;126(4):1108–1116

[31] Miyebi JI, Daniel EO, Ezeanya CC. Listeria species as contaminants among Lettuce sold in some vegetable markets in Benin City, Nigeria and its resistance genes. Nigerian Journal of Biotechnology. 2018; 35(2):151-158.

[32] Gao H, Zhao X, Chen S. AIEgen-based fluorescent nanomaterials: fabrication and biological applications. Molecules. 2018a; 23(2):419.

[33] Ezeanya CC, Agbakoba NR, Ejike CE, Okwelogu SI. Evaluation of a Chromogenic Medium for the Detection of ESBL with Comparison to Double Disk Synergy Test. British Journal of Medicine and Medical Research. 2017; 21(12): 1-11.

[34] Gao Y, Wijewardhana C, Mann JFS. Virus-like particle, liposome, and polymeric particle-based vaccines against HIV-1. Frontier in Immunology. 2018b; 9:345.

[35] Ejike CE, Agbakoba NR, Ezeanya CC, Emele FE, Oguejiofor CB. NonAlbicans Candida among Symptomatic Vulvovaginal Candidiasis Women in Onitsha, Nigeria. International Journal of Health Sciences and Research. 2017; 7(6): 84-89.

[36] Ebenebe JC, Emeka-Okafor KM, Akujobi CN, Ezeanya CC, Agbakoba NR, Egwuatu CC. Plasmid Profile of Uropathogens among Children. British Journal of Medicine and Medical Research. 2014; 4(5): 1195-1203.

[37] Akujobi CN, Ilo IA, Egwuatu CC, Ezeanya CC. Prevalence of methicillin resistant Staphylococcus aureus (MRSA) among healthcare workers in a tertiary institution in Nigeria. Orient Journal of Medicine 2013; 25(3-4): 82-87.

[38] Gleich B, Weizenecker J. Tomographic imaging using the nonlinear response of magnetic particles. Nature. 2005; 435:1214–1217.

[39] Akujobi CN, Ezeanya CC, Emeka-Okafor KM, Ebenebe JC. A Study on Significant Bacteriuria among Children attending the Out-patient Clinic of a University Teaching Hospital, Nigeria. International Journal of Microbiology Research. 2013; 5(4): 448-451.

[40] Akujobi CN, Ezeanya CC, Madu OJ, Egwuatu CC. Carbapenem Susceptibility Pattern among Pseudomonas aeruginosa isolates from clinical specimens in South Eastern Nigeria. Journal of Pharmaceutical and Biomedical Sciences. 2013; 33(33): 1491-1494.

[41] Gunalan S, Sivaraj R, Rajendran V. Green synthesized ZnO nanoparticles against bacterial and fungal pathogens. Prog National Science: Material & International. 2012; 22:693–700

[42] Akujobi CN, Ezeanya CC. Emergence of Carbapenem resistance among Extended Spectrum Beta-lactamase isolates of Escherichia coli from clinical specimens in a tertiary hospital, Nigeria. International Journal of Microbiology Research 2013; 5(2): 366-369.

[43] Hajba L, Guttman A. The use of magnetic nanoparticles in cancer theranostics: toward handheld diagnostic devices. Biotechnology Advancement. 2016; 34:354–361.

[44] Ezeanya CC, Daniel E O. Antibacterial Activity of Garcinia kola seed and leaf extract on some selected clinical isolates. Science Journal of Microbiology 2012; doi:10.7237/sjmb/298.

[45] Emily B. Ehlerding, Piotr Grodzinski, Weibo Cai, and Christina H. Liu. Big Potential from Small Agents: Nanoparticles for Imaging-Based Companion Diagnostics. ACS Nanotechnology 2018; 12 (3); 2106-2121