

Bio Fabricated Selenium Nanoparticles And Their Therapeutic Potential: Bridging The Gap Between Elemental Selenium And Bio-Fabricated Nano Selenium

Srilakshmi Samanchi^{1,6*}, Josthna P², Ratnasri P.V³, Heerekar Ambika⁴, Yella Ramya⁵, Bramarambica K⁷

¹*Research Scholar, Department of Biotechnology, Sri Padmavathi University, Tirupati-517502, Andhra Pradesh, India.

²Professor, Department Biotechnology, Sri Padmavathi University, Tirupati-517502, Andhra Pradesh, India.

³Assistant manager, Clinical Pathology Laboratory, Jeevan Scientific Technology Ltd., Hyderabad-500037, Telangana, India.

⁴Research Scholar, Department of Engineering and Biotechnology, GITAM University, Visakhapatnam-530045, Andhra Pradesh, India.

⁵Lecture in Microbiology, Samhitha Degree College, Rajahmundry-533101, Andhra Pradesh, India.

⁶Assistant Professor, Andhra Loyola College, Vijayawada-520008, Andhra Pradesh India.

⁷Associate Professor, R&D, Lalata Technologies (www.lalatastechnologies.com).

ABSTRACT

Recently, in the field of biotechnology, the integration of diverse chemical elements like nickel, copper, molybdenum, Selenium (Se), and so on has increased. Out of these elements, Se is one of the vital chemical elements used in biotechnology for its therapeutic and clinical treatments and Antioxidant (AO), Anticancer (AC), and Antimicrobial (AM) roles. Recent advances in biotechnology have led to the development of synthesized nano-Se to advance the therapeutic range of Se. The synthesized Nano Selenium (NS) offers improved bioavailability, higher biological activity, etc., with reduced toxicity levels. The characteristics like enhanced bioavailability, increased biological efficacy, and minimized toxicity are collectively attributed to a process known as Bio-Fabrication (BF), where biological systems or processes are utilized to design and develop nanomaterials with superior functional properties. The Biofabricated Se Nanoparticles (SeNPs) have shown improved results among the various synthesized nano-Se. The BF method uses plants, fungi, or other biological sources to create the SeNPs for enhanced therapeutic potential. It aims to highlight their potential as safer and more effective alternatives to conventional Se forms, especially in AM, AC, and AO therapies. Moreover, the review identifies existing gaps in current research and emphasizes the importance of overcoming challenges, such as source dependency, environmental factors, and regulatory barriers..

Keywords: Selenium Nanoparticles, Bio-fabrication, Green Synthesis, Anti-microbial, Anticancer, Antioxidant, nano selenium, and elemental selenium..

How to cite this article: Samanchi S, P J, P.V R, Ambika H, Ramya Y, Bramarambica K, Bio Fabricated Selenium Nanoparticles And Their Therapeutic Potential: Bridging The Gap Between Elemental Selenium And Bio-Fabricated Nano Selenium. *Int J Drug Deliv Technol.* 2026;16(2s): 408-419; DOI: 10.25258/ijddt.16. 408-419

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Diverse chemical elements like nickel, copper, molybdenum, Se, etc., are used in clinical and therapeutic applications in the field of biotechnology. Out of these elements, one of the important chemical elements is Se. Se, a nutrient element that has a massive function in biological systems, and is a significant compound to integrate with antibacterial agents [1]. Thus, the elemental Se and the Biofabricated SeNPs are utilized in the therapeutic applications due to their increased biological importance. Yet, due to their toxicity scale and their limited therapeutic range, the therapeutic applications of Biofabricated SeNPs have been limited [2].

These limitations act as a challenge to its effective therapeutic use. To overcome the limitations, recent advancements in biotechnology have introduced nano-Se (NS) for therapeutic applications. The NS is engineered at the nano scale, attracting growing attention owing to its (A)

excellent bioavailability, (B) high biological activity, and (C) low toxicity [3]. Moreover, the NS has an easily regulated size, controlled release, low cytotoxicity, along with improved AC efficacy [4]. Moreover, the NS is synthesized to create SeNP for improving the therapy applications to the next level. Among various approaches to synthesize NS, BF has emerged as an effective alternative. This method leverages biological organisms or botanical extracts, such as plant extracts, fungi, etc, to produce SeNPs [5]. Also, the Biofabricated SeNPs exhibit physicochemical properties, namely low toxicity levels, high adsorption capacity, and so on, compared to the traditional Se and Biofabricated Se. Also, the Biofabricated SeNPs show positive results in therapy in AM, AC, and AO roles. The results obtained from the SeNPs highlight the Biofabricated SeNPs as an effective alternative to the conventional and chemically prepared Se.

Thus, this review explores the significance of the Biofabricated SeNPs as a safer and effective replacement

*Author for Correspondence: Srilakshmi Samanchi

for elemental Se. Likewise, the study addresses the need for biocompatibility of Se nanostructures in therapeutic biotechnology to reduce the adverse effects in therapeutic applications. Also, the motivation of the study lies in the growing demand for non-toxic therapeutic agents, which has driven the exploration of the Biofabricated SeNPs. Also, the Biofabricated SeNPs are proven to provide effective benefits in the therapeutic application against AC, AM, and AO properties. Further, this review aims to analyse the gaps in the existing studies for bridging the gap between elemental Se and the Biofabricated SeNPs. Further, the Biofabricated SeNPs can be applied in the anti-microbial, anti-oxidant, and AC therapies. This results in ensuring the safety and effectiveness of the therapeutic applications. Thus, the review paper is structured in the following way: Introduction section, followed by research questions (RQs) and article selection (**“Section 2”**), literature review (**“Section 3”**), summary and problem definition (**“Section 4”**), and lastly, conclusion section (**“Section 5”**).

RQs AND ARTICLE SELECTION STRATEGY

The RQs framed show the significance of the review. The RQs related to the concept of this review include: How do the Biofabricated SeNPs differ from elemental Se? How do

the Biofabricated SeNPs work against infections and cancer? How do the Biofabricated SeNPs improve the drug delivery in the treatments compared with the conventional Se? What are the significant reductions of adverse effects when using Biofabricated SeNPs in the therapeutic applications? and finally, what are the challenges that must be overcome for the application of the Biofabricated SeNPs in advanced therapeutic applications?.

Also, significant databases like Science Direct, Web of Science, IEEE, and Scopus, were wielded in the selection of research articles. The publications included in the review of Biofabricated SeNPs and their therapeutic potential bridge the gap between elemental Se and Biofabricated NS. The articles that were published before 2016 were excluded, and a list of keywords, such as “SeNPs”, “BF”, “Green Synthesis”, “Anti-microbial, AC”, “AO”, “NS”, and “elemental Se,” was used for the search strategy.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was employed to ensure that the review of Biofabricated SeNPs and their therapeutic potential to bridge the gap between elemental Se and Biofabricated SeNPs was conducted in a clear, organised, and consistent way. The representation of PRISMA is shown in Figure 1.

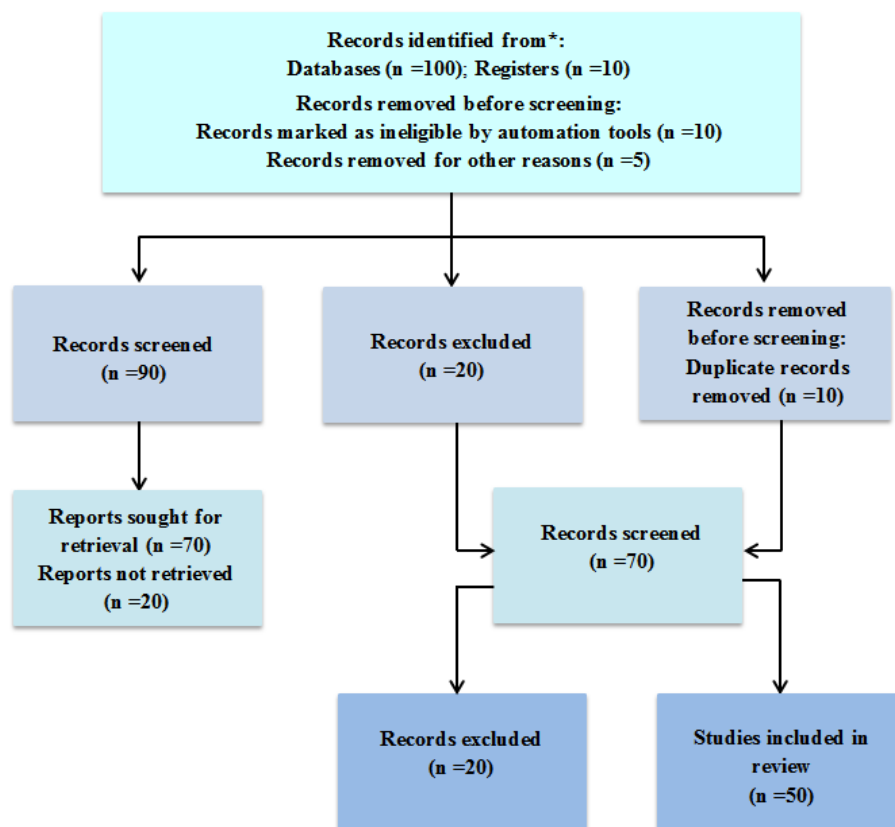


Figure 1: PRISMA Framework

LITERATURE REVIEW

This section aims to investigate the role of Biofabricated SeNPs and their potential therapeutic applications in the

AC, AM, and AO roles. Moreover, the challenges and the regulatory issues of the Biofabricated SeNPs during their therapeutic applications are also explored in the section to present a clear and concise view of the BIOFABRICATED SeNPs.

3.1. BIOFABRICATED SeNPs: Detailed Overview

BIOFABRICATED SeNPs are the nano-sized Se elements that are used for various applications like agricultural, biomedical, cosmetics, coatings, and packaging. Yet, the SeNPs have significant biological applications [6] and are widely used in the field of biotechnology. Moreover, the BF process of SeNPs includes only the natural extracts for its eco-friendly behaviour. Especially, the phytochemicals that are the backbone of plants help to easily engender Nanoparticles (NPs) with less toxicity [7]. But, the research studies conducted based on the animal studies using Biofabricated SeNPs were relatively fewer when compared with the other research studies conducted on Biofabricated SeNPs based on the plant studies. So, in this section, this review focuses more on the plant-based Biofabricated SeNPs rather than animal-based studies.

Also, the study [8] also used the sustainably synthesized Biofabricated SeNPs as a seed printing agent for germination on *Oryza Sativa L.* Thus, the findings highlighted that the efficacy of the SeNPs augmented the seed germination, embryo viability, along with seedling vigour. Likewise, the study [9] explored the synergistic mitigation of aluminium toxicity in rice using the Biofabricated SeNPs and nitric oxide. Also, the findings

revealed that the combined treatment with SNP and Biofabricated SeNPs enhanced aluminium tolerance with regulated sulphur metabolism. Following this, the study [10] aimed to bio-fabricate the SeNPs along with assessing the foliar applications for improving wheat plants' growth under controlled irrigation and drought stress. A key role is played by SeNPs in augmenting the drought tolerance along with the growth of wheat plants under severe drought stress. Afterward, the study [11] employed Biofabricated SeNPs from the *Goniothalamus wightii* for biomedical applications along with photocatalytic degrading ability. Likewise, the results depicted that the synthesized SeNPs had good antibacterial potential on the strains of Gram-positive and Gram-negative pathogens.

Lastly, the study [12] used the pineapple peel waste extract to biofabricate the SeNPs, aimed at various medical uses. Also, the formed SeNPs demonstrated enhanced AC effectiveness. Despite the promising results, some of the notable challenges were included in the Biofabricated SeNPs.

Also, Table 1 presents the important parameters of the Biofabricated SeNPs investigated from the discussed research articles for a better understanding of the behaviour of Biofabricated SeNPs.

Table 1: Important parameters of the bio-fabricated SeNPs investigated from the above-discussed research articles

Authors' name	Study type	Extraction	Size (nm)	Findings						Challenges
				Intensity	Absorbance	Transmittance	Concentration	Fourier Transform InfraRed spectroscopy (FTIR) rate	(Energy Dispersive X-Ray) EDX rate	
Salem [6]	Experimental research	Baker's Yeast	Between 04 and 51 nm	101 nm	300 nm	1609.1	62.5, 125, 250, and 500 µg/mL	617.1 cm ⁻¹	Nil	Variability in nanoparticle size and lack of toxicity data.
Venkatesan & Sujatha [7]	Experimental research	Withania Somnifera leaf extract	45 to 90 nm	657 nm	1.8	Nil	12.74, 40.54, and 156.33 µg/mg	3434 cm ⁻¹	Weight % : 50.79 and Atomic % : 66.79	Amorphous nature and limited long-term stability of SeNPs.
Jyotsna, et al., [8]	Applied experimental study	Raisin extract	300 to 600 nm	233.55 cm ⁻¹	Between 1800 and 1500 cm ⁻¹	3423 cm ⁻¹	10 to 30 Mm	Nil	Nil	Standardization of nanoparticle formulation and increased cost of nanoparticle production.
Abir, et al., [9]	Mechanistic experimental study	Salvinia molesta D. Mitch. extract	~67 nm	29.7557	0.8	Nil	5 mM and 20 mL	Nil	Nil	Limited nanoparticle penetration and mobility in plants.
Muhammad, et al., [10]	Applied experimental study	Allium sativum L.	257 nm	Nil	257 nm	Nil	Nil	Nil	2.5 and 3.0KeV	Shorter shelf life of SeNPs.
Chinnaraj, et al., [11]	Experimental study	Goniothalamus wightii	265 nm	111	265 nm	~3500	74.12 (µg/mL)	Nil	Nil	Limited In Vivo therapeutic validation.
Mohamed, et al., [12]	Applied experimental study	Ananas comosus peel	Between 33 and 73 nm	101	1.4	1596	62.5–31.25 µg/mL	Nil	Nil	Ant biofilm effectiveness limitations and a moderate antioxidant property.

The above table investigates the characterization of the SeNPs using notable parameters like size, intensity, absorbance, transmittance, and so on. Further, from the above table, the research study presented by Jyotsna, et al., [8] reported the largest NP size of Se along with the highest intensity range. This indicated larger and potentially more dispersed particles. On the other hand, the research study conducted by Salem, et al., [6] achieved the smallest NP size with the highest absorbance value and transmittance value compared to the other discussed studies. This suggested higher optical activity and smaller particles. In terms of the concentration, the study presented by Chinnaraj, et al., [11] highlighted the highest concentration, while the study presented by Abir, et al., [9] had the lowest concentration rate. Further, in the research publication conducted by Chinnaraj, et al., [11], the FTIR rate was also higher. Ultimately, these variations highlighted the influence of different biological sources and synthesis methods on SeNPs' properties.

3.2. Therapeutic potential of Biofabricated SeNPs

The Se elements are widely used in diverse therapeutic applications, like AO, AM, and AC roles. Among the Se elements, the Biofabricated SeNPs (also known as green synthesized SeNPs) are used in such therapeutic roles. The BF method uses natural plants and microbes to fabricate the SeNPs for providing the enhanced therapeutic application [13]. Moreover, the BF process has shown promising effects against diseases. Due to the challenges like structural instability and unclear or varying chemical structure in the BF techniques of SeNPs, complete adaptability is difficult in the therapeutic applications.

In the study [14], the SeNPs' therapeutic potential derived from purple sweet potato (PSP) extracts was explored for promoting wound healing regarding antibacterial effectiveness. Likewise, the PSP-SeNPs demonstrated excellent biocompatibility and hemocompatibility, recommending significant therapeutic promise meant for broader biomedical applications. Next, the study [15] examined the clove of Aloe Vera, which was wielded for SeNPs' synthesis to examine its AO potential. The experimental analysis reported that the SeNPs prepared by employing Aloe Vera extract possessed more AO activity when analogized to the extract alone. This suggested the considerable therapeutic promise for broader biomedical applications.

Also, the natural penicillium extracts were used for the BF process, and the SeNPs' therapeutic properties were analysed in both studies [16] and [17]. As mentioned in study [16], the antibacterial and cytotoxicity of green-synthesized SeNPs by employing *Penicillium corylophilum* were explored. The experimental results highlighted that

Se-NPs exhibited broad-spectrum activity against pathogenic Gram-positive along with Gram-negative bacteria. Similarly, in the study [17], SeNPs' biosynthesis process was performed using *Penicillium expansum* ATCC 36200 for numerous biomedical properties, like AM, AO, AC activities, along with hemocompatibility. Next, the results indicated a high AO and AC potential, indicating that the Se-NPs by *P. expansum* were promising for several safe-use biomedical applications. Further, the studies [18] and [19] used the polysaccharides of plants as their key components for the examination of the AO, AM, along with AC activities of the Biofabricated SeNPs. The research [18] aimed to investigate SeNPs' AO activity stabilized by the polysaccharides of *Grateloupia filicina* (GFP). GFPsSeNPs depicted a higher AO activity when weighed against GFPs as well as SeNPs alone. Likewise, the study [19] used the polysaccharide of mangrove *Rhizophora mucronata* (RMLP) to investigate the AO and AM properties of the SeNPs. Besides, the RMLP-SeNPs showed good AM along with antibiofilm activity against tested strains like *Aeromonas hydrophila*, *Escherichia coli*, *Staphylococcus aureus*, along with *Pseudomonas aeruginosa*.

Also, in the research study [20], the Se-NPs were analysed with an aim on their photocatalytic applications, cytotoxicity, along with AM activities. Besides, Se-NPs depicted a vital photocatalytic effects; also, exhibited effects in overpowering the growth of harmful microorganisms. Next, Cytotoxicity exploration and SeNPs' AM efficiency biosynthesized by *Spirulina platensis* was explored in the study [21]. The Biofabricated SeNPs depicted latent AM activity against gram-negative bacteria and yeast fungi *C. albicans* ATCC 10231. Lastly, the evaluation of in-vitro AO, anti-inflammatory, along with anti-diabetic properties of SeNPs derived from *Nigella Sativa* seeds was carried out in the research [22]. Ultimately, the findings showed that SeNPs synthesized from *Nigella Sativa* enhanced AO, anti-inflammatory, and anti-diabetic activities, highlighting their therapeutic potential.

These findings from the Biofabricated SeNPs bridge traditional herbal medicine and nanotechnology, offering a promising pathway for sustainable interventions against chronic diseases. Besides, green-synthesized SeNPs' prospects represented a potential breakthrough in addressing the complexities of wound healing along with other biomedical challenges, like the anti-microbial and AO therapeutic applications. Also, the findings and the advanced therapeutic capabilities of the Biofabricated SeNPs investigated from the above-discussed research articles are tabulated in Table 2.

Table 2: Significant parameters highlighting the therapeutic potential of bio-fabricated SeNPs from the above-discussed research articles.

Key Extraction component(s)	Nanoparticles Size	Findings							Challenges	References
		Hemolysis Rate	Transmittance	Intensity	Cell Viability	Inhibition zone	2, 2 DiPhenyl -1- PierylHydrazyl (DPPH) Rate	2, 2'Azino-Bis (3- ethylbenzo Thiazoline-6- Sulfonic acid) (ABTS) Rate		
Allium cepa, Malpighia emarginata, and Gymnanthemum amygdalinum	between 245 and 321 nm	0.82 to 2.1 mg/ml	1606 cm-1	101	Nil	Nil	Nil	Nil	Selectivity towards only the Gram-positive bacteria and an unclear antibacterial mechanism	[13]
purple sweet potato	80–100 nm	<5 %	Nil	101	~120	Nil	Nil	Nil	Complexity in pyroptosis regulation in humans and Regulatory and barriers	[14]
Leaf extracts of Aloe Vera	7-48 nm	Nil	Nil	Nil	Nil	~80%-90%	90%	80%-90%	Lack of in vivo and clinical validation, Limited functional assessment of antimicrobial property	[15]
Penicillium corylophilum	29.1-48.9 nm	Nil	Nil	~35%	171.82 ml	20 mm	Nil	Nil	Lack of regulatory approval and biosafety, and Lack of cytotoxicity validation	[16]
Penicillium expansum ATTC 36200	4 to 12.7 nm	250 µg/mL	1620.8	600	Nil	~27%	Nil	Nil	Limited anticancer-related therapeutic index	[17]
Polysaccharides Isolated from Grateloupia filicina	100 nm	Nil	Nil	Nil	Nil	Nil	~82%	Nil	A narrow margin between the toxic and functional dosage.	[18]
Polysaccharide of mangrove Rhizophora mucronata	around 54.85 nm	Nil	Nil	Nil	Nil	12.50%	~60%	~70%	poor stability and low cellular accumulation in SeNPs	[19]
Cuminum cyminum L extract	approximately 46 nm and 45 nm	Nil	1070	7000 counts	100%	Nil	Nil	Nil	Limited antimicrobial spectrum and no evaluation on toxicity and environmental safety	[20]
Spirulina platensis	79.40 ± 44.26 nm	Nil	45%	Nil	95%	45mm	Nil	Nil	High variability in the shape of SeNPs and no long-term cytotoxicity testing	[21]
Nigella Sativa seeds	45-60 nm	Nil	Nil	Nil	Nil	80.50%	85.2±2.0	88.3±2.3	Lack of toxicity data and no in vivo validation	[22]

The above table investigates the significant findings from the therapeutic potential of the Biofabricated SeNPs in various treatments like AO, AM, and AC roles using the metrics, such as Hemolysis rate, cell viability, DPPH rate, etc. Among the studies, the research study presented by Heba, et al., [21] reported the highest AO performance with the highest DPPH and cell viability scores. Next, the study conducted by Jay & Rana [15] demonstrated the highest antibacterial effect with increased inhibition zone, even though it lacked the long-term cytotoxicity data. Further, the research article published by Fatemah, et al., [20] using the cuminum extract showed 100% cell viability and extremely increased intensity counts. This showed a better bioactivity, yet lacked the microbial and AO effects. In contrast, the studies presented by the authors Natwar, et al., [19], Kehinde, et al., [22], and Amr, et al., [17] showed incomplete data and low therapeutic outputs with major challenges like poor stability and selectivity. Thus, the studies conducted by Kehinde, et al., [22] and Heba, et al., [21] utilised the Biofabricated SeNPs, which provided the most promising results with balanced performance in the therapeutic applications.

3.3. Bio-fabrication methods and characterization of SeNPs

The SeNPs' BF process was done to enhance the therapeutic potential. Different fabrication methods were used to prepare SeNPs with different morphologies and sizes [23]. Also, the characteristics of the Biofabricated SeNPs highlighted their capability for therapeutic applications.

Analysis is done by diverse methods like Ultraviolet Visible Spectroscopy (UV-vis), FTIR, Scanning ElectronMicroscopy-Energy Dispersive X-ray (SEM-EDX), Transmission Electron Microscopy (TEM), Dynamic Light Scattering (DLS), along with Zeta potential measurements. AO, along with in-vitro cytotoxicity properties in the research studies, was analysed by using diverse experimental parameters like AO activity, molecular docking, and fluorescent spectra. [24].

Further, the study [25] explored the FTIR as well as Raman spectroscopic characterization of SeNPs synthesized using the bacterium *Azospirillum thioophilum*. Using the combination of FTIR and Raman spectroscopic approaches, it was shown that proteins' secondary structure remained unchanged, recommending that the synthesized nano-Se might be wielded as a carrier in the drug delivery system devoid of any cytotoxicity effect. Afterward, the study [26] aimed to biofabricate the SeNPs by employing *Moringa oleifera* leaf extract (MOLE) and analogizing the MOLE-SeNPs' protective effects. Besides, the study provided evidence that the MOLE-SeNPs extract increased melamine-induced nephrotoxicity, which was capable of reducing the renal function impairments, oxidative stress, along with apoptosis. The study [27] investigated the synthesizing process of SeNPs using *O. gratissimum* and explored their AM activities. Also, the bio-synthesized SeNPs by *O. gratissimum* depicted higher AM activity against the gram-positive along with gram-negative bacteria.

Following the above-mentioned research studies, the studies [28] and [29] focused on the investigation of the characteristics and synthesizing methods of Biofabricated SeNPs for the detailed exploration of their characterization. The study [28] used the natural extracts of *Capparis decidua* for the BF process, and the characterization was analysed using the ultra-visible spectroscopy along with Transmission Electron Microscope [TEM]. Further, the study concluded that the prepared SeNPs were eco-friendly and contained rich medicinal properties with fewer side effects. Next, in the study [29], the SeNPs were synthesized with the bacterial exopolysaccharides and verified through the UV-Vis spectral examination. The findings showed that the Biofabricated SeNPs exhibited the highest TEM characteristics and the enhanced potential for medical applications.

Also, some other research papers solely focused on the BF process of SeNPs, which demonstrated enhanced properties

of SeNPs. The study [30] focused on the BF of SeNPs using the *P. aeruginosa* for bioremediation. Furthermore, the tested bacterial strain depicted vital selenite reduction activity. This indicated that the SeNPs had higher potential in medical applications. Next, the study [31] also focused on SeNPs' biosynthesis by employing microbes of the bacillus species. The highest zone of inhibition indicated that the microbial synthesised SeNPs would be an efficient medicine due to their AO and AM activity. At last, in study [32], the Biofabricated SeNPs used *B.paramycoides 24522*. The fabrication process exhibited lethality against *Staphylococcus aureus* along with *Escherichia coli* with propitious AO capabilities via scavenging DPPH radicals as well as minimizing power.

Also, the detailed investigation of BF methods and characteristics of SeNPs from the above-discussed research articles is tabulated in Table 3.

Table 3: Detailed investigation of Bio-fabrication methods and characteristics of SeNPs from the above-discussed research articles

Authors' Name	Biofabrication methods	Analysed characterizations	Findings								Challenges
			Zeta potential	TEM	DLS	FTIR spectroscopy	DPHH	Inhibition zone	Cell Viability	Absorbance spectra	
Safeih, et al., [23]	Ascorbic acid and Polyvinyl alcohol	DLS, FITR, TEM, MTT	Nil	Nil	Nil	1594.34 cm ⁻¹ ,	100%	13.5mm	100% (in 24 hr)	200-700 nm.	Instability of SeNPs and variation of antioxidant activity
Nahid, et al., [24]	et-DNA and HSA, HbB and Cyt c serum proteins	FT-IR, SEM-EDX, TEM, DLS, and zeta potential measurements	5000	Nil	50%	4000-400 cm ¹	Nil	~62%	100%	1:1 ratio (1 mg/mL).	Limited biocompatibility in the SeNPs
Anna, et al., [25]	bacterium Azospirillum thiophilum	FITR, Raman Spectroscopy, TEM, DLS	-18.5 mV	Nil	160-250 nm	250 cm ⁻¹	Nil	Nil	Nil	Nil	Uncertain size and polydispersity of SeNPs
Ehsan, et al., [26]	Moringa oleifera leaf extract	TEM, Absorbance spectra	Nil	100nm	Nil	Nil	Nil	Nil	Nil	400 and 700nm	Variable effectiveness between individuals and biological complexity
Gbemisola, et al., [27]	Ocimum gratissimum	TEM, SEM, FITR	1000	20 nm - 100 nm	Nil	3458.00 cm ⁻¹	Nil	Nil	Nil	2.5	Variability in particle size and a lack of an antibacterial mechanism
Madhumita, et al., [28]	Ocimum gratissimum	TEM	Nil	320 nm	Nil	Nil	Nil	Nil	Nil	Nil	Lack of characterization data and no biological evaluation
Thirumalaivasan, et al., [29]	Bacterial (Bacillus sp. MKUST-01) exopolysaccharides (EPS).	Nil	Nil	Nil	Nil	3425 cm ¹ , 2926 cm ¹ , 1639 cm ¹ , and 1411 cm ¹	80%	Nil	80%	0.3	Low dispersion stability and incomplete toxicity details
Aruna, et al., [30]	bacterial strain Pseudomonas aeruginosa	Raman spectroscopy, SEM, DLS, TEM, and FTIR	Nil	95.9 ± 35.9 nm	Nil	Nil	Nil	Nil	Nil	1.0 mM	Amorphous nature of SeNPs nanoparticles
Greeshma & Mahesh [31]	Bacillus species	SEM	Nil	Nil	Nil	3200cm ⁻¹	Nil	1.7 cm and 2.5 cm	Nil	Nil	Lack of cytotoxicity or biocompatibility assessment
Pei, et al., [32]	Bacterium Bacillus paramycoides 24522.	Nil	Nil	Nil	Nil	Nil	82%	Nil	Nil	0.8	Lack of particle size of SeNPs

The above table investigates the characterizations of the SeNPs, such as zeta potential, DPHH, cell viability, etc., to explore the detailed characteristic understanding of the Biofabricated SeNPs. The study presented by Shafeih, et al., [23] showed high AO activity but faced NP instability. The research published by Nahid, et al., [24] reported a moderate biocompatibility with limited overall safety. Following this, the research study conducted by Nahid, et al., [24] and thirumalaivasan, et al., [29] exhibited a higher FTIR spectroscopy compared to the other studies, which indicated a higher characterization potential. On the other

hand, the research studies presented by Aruna, et al., [25] and Greeshma & Mahesh lacked cytotoxicity and biological data assessment, even though the studies provided enhanced characterization standards. Lastly, the research study conducted by Nahid, et al., [24] depicted higher TEM spectroscopy compared to the study conducted by Gbemisola, et al., [27], which showed an enhanced SeNPs size with higher therapeutic potential.

3.4. Mechanism of actions of BIOFABRICATED SeNPs

The Biofabricated SeNPs exhibited various mechanisms of action, such as AO activity, AM activity, etc., for the enhancement of the therapeutic potential [33]. These action

mechanisms explained the capacity of the SeNPs particles [34] and the complete investigation of their potential in the role of therapeutic applications against microbial and cancer diseases. The study [35] aimed to demonstrate SeNPs' effects on the growth performance, AO status, along with immunity analysis in fish. Moreover, the SeNPs enhanced the capability to alleviate multiple stresses in the *Pangasinodon 65* hypothalamus. Next, the study [36] evaluated the AC effectiveness of the SeNPs using curcumin. The results highlighted an augmented ROS level and decreased mitochondrial membrane potential, along with apoptosis in the HCT116 cells. Besides, in the study [37], the biogenic SeNPs were Biofabricated using the cyanobacteria, and their bioactivities were discussed. This study compared the SeNPs with the commercially available SeNPs. Also, the findings showed that the Biofabricated SeNPs showed higher bioactivities compared to the chemically altered SeNPs, recommending biomedical application's higher probability. Then, the study [38] explored the mechanisms of the Biofabricated SeNPs using the *Fusarium fujikuroi* MED14. The Se NPs depicted antifungal activity against *F. solani*, *Aspergillus niger*, *F. fujikuroi* MED14, along with *Candida albicans*, with higher inhibition zones. Also, the study [39] explored the targeted delivery of paclitaxel by Biofabricated SeNPs for AC therapy via ROS-mediated signalling pathways. As a result of the analysis, it

was demonstrated that the SeNPs provided an enhanced therapy for cancer using the targeted nano systems. Likewise, the research study [40] constructed the *Cordyceps sinensis* expolysaccharides-conjugated SeNPs, along with analysed the enhancement of their AO activities. The overall findings showed significant scavenging ability, but also found that the EPS-SeNPs could serve as a good AO. Ultimately, in the research study [41], the selenite ions were minimized to the SeNPs by employing the leaf extract of barley, and the synthesized action mechanisms were evaluated using the SEM technique and IV spectrophotometry. The findings offered the 1st evidence that the green Se NPs promoted barley seedlings' growth under salt stress. Lastly, in the research study [42], the preparation of SeNPs by employing Indian Gooseberry's fruit extract was carried out, and the structural properties were analysed. This showed that the prepared SeNPs depicted vital inhibition of bacterial growth at a lower Minimum Inhibitory Concentration (MIC). These action mechanisms and the structural characterization analysis showed the enhanced potential of the Biofabricated SeNPs over elemental Se. Further, the significant mechanisms of action and characterization of the Biofabricated SeNPs from the above-discussed research articles were investigated and tabulated in Table 4.

Table 4: Significant mechanisms of action and characterization of the biofabricated SeNPs from the above-discussed research articles

Study type	Bio components used	Mechanism of Actions	Adverse effects reported	Findings				Challenges	References
				Antimicrobial activity	Transmittance	Intensity	Bacterial pathogens		
Experimental research study	<i>Streptomyces</i> sp. (M10A65)	Antibacterial Activity and Anthelmintic Activity Mechanism	Nil	80%	3300.74	14%	0.9	Isolation and Identification of Effective Microbial Strains	[33]
Controlled experimental study	Lycopene	Antioxidant and Antiapoptotic Activities	Histopathological damage	Nil	Nil	Nil	Nil	Lack of delivery and dosage optimization, complexity of nanoparticle synthesis	[34]
Research study	dietary selenium nanoparticles	Growth performance and Antioxidant defence	Mild toxicity and Immune suppression	2.56	Nil	1	Nil	Complex response variability	[35]
Experimental study	Curcumin	ROS production and cell cycle arrest	Nil	96%	Nil	1	Nil	Complexity in the targeted delivery system	[36]
Comparative in vitro study	<i>Anabaena variabilis</i> NCCU-441	Antioxidant, Antimicrobial, and anticancer effectiveness	Cytotoxicity to normal cells	100%	3212.91	20	16	Standardization of nanoparticle quality	[37]
Experimental in vitro study	<i>Fusarium fujikuroi</i> MED14	ROS, Particle size effects	Nil	Nil	246 nm	Nil	Nil	Lack of uniformity and stability of SeNPs	[38]
Experimental study	b-cyclodextrin (b-CD)-folate	ROS, Particle size effects	Nil	20%	Nil	200nm	150	Need for targeted delivery	[39]
Experimental synthesis and characterization study	<i>Cordyceps sinensis</i>	Antioxidant activity	Nil	Nil	Nil	3	Nil	Difficulty in achieving stable SeNPs	[40]
Experimental study	barley plants	Antioxidant effects and Antibacterial effects	Nil	Nil	Nil	Nil	Nil	Increased oxidative damage due to the shoot growth	[41]
Evaluation study	Indian gooseberry(<i>PhyllanthusEmblica</i>)	Antibacterial mechanism	Oxidative stress and Inflammatory responses	517nm	Nil	Nil	97%	Lack of stable nanoparticles	[42]

The above table explains the action mechanisms of the characteristics of the SeNPs using important metrics like AM activity, reported adverse effects, etc. Among the studies, the research study by Bushra, et al., [37] showed the highest AM activity and strong intensity compared to the other studies. Furthermore, the study by Manisha, et al., [36] showcased the highest transmittance rate and reported no adverse effects. This highlighted the safe and potent AO role. Also, the study presented by Suseenthar, et al., [33] performed well but lacked delivery innovation. Lastly, the research study presented by Ishita, et al., [42] highlighted strong bacterial reduction but lacked the NP consistency, making it lower in the stability rate.

3.5. Challenges in the therapeutic applications of SeNPs

The biological approaches of the Biofabricated SeNPs offered advantages by minimizing production costs, diminishing toxicity, along with augmenting biocompatibility [43] as they evade dipping agents along with stabilizing agents' usage. Natural extracts not just support SeNP formation but also augment their stability along with biological functionality. Despite the advantages, there were some notable challenges in the therapeutic, like unstable NPs, unclear particle mechanism, etc.

Further, the study [44] explored the role of Biofabricated SeNPs in the field of biomedical science. The findings highlighted the nanosizing of SeNPs' significance on the pharmacological activity. Yet, the challenges like drug delivery, imaging, therapeutics, and diagnostics procedures were reduced to achieve the higher potential of the SeNPs. Next, the study [45] investigated the synthesis of the Biofabricated SeNPs using the halophilic bacteria. Also, it was characterized using the UV-Vis, FTIR, EDX, etc. Yet,

the Biofabricated SeNPs were used due to their effectiveness and flexibility. The storage concerns and the particle stability were notable challenges that still existed in the process.

The research study [46] explored the synthesis technique to engender the SeNPs with consistent size, along with distribution to evaluate the potential effects. The findings showed that the SeNPs offered a propitious therapeutic approach by restoring the mitochondrial function along with redox homeostasis. Also, the research study [47] utilised the probiotics to synthesize the SeNPs, which achieved the large-scale application and enhanced therapeutic results. Nonetheless, the instability in the molecular mechanism and the lack of in vitro assessment were the challenges. Further, in the study [48], the SeNPs were stabilized with the glucan and rosamarinic acid to stabilize the SeNPs. However, the unstable mechanism and the lack of storage assessment downgraded the potential therapeutic application of the SeNPs.

Lastly, to enhance the potentiality of the therapeutic application of SeNPs, the studies [49] and [50] synthesized the SeNPs by different methods. The research study [49] used the *Streptomyces parvulus MAR4* and *Nch* for the BF process, which provided high stability. Yet, the process resulted in an unstable particle size. Similarly, by using the microbial reduction process, the study [50] was Biofabricated under anaerobic and aerobic conditions. Yet, the polydispersity nature of the biogenic SeNPs and their size variability resulted in the restriction of the therapeutic applications. Also, in Table 5, the challenges of the BF process in the SeNPs from the discussed research articles are analysed and tabulated.

Table 5: Challenges of the Bio-fabrication process in the SeNPs from the discussed research articles

Study type	Unstable Molecular mechanism	Particle Size Variability	Storage incompatibility	Lack of in vivo assessment	Targeted drug delivery	Imaging therapeutics	Polydispersity	Lack of clinical trials	References
Experimental analysis	X	X	X	X				X	[43]
Comparative analysis	X	X	X	X				X	[44]
Experimental analysis	X			X	X	X	X	X	[45]
Experimental analysis	X	X	X		X	X	X		[46]
Experimental analysis		X	X		X	X	X	X	[47]
Experimental analysis	X			X	X		X	X	[48]

Comparative analysis	X		X	X	X	X	X	X	[49]
Comparative analysis	X	X	X	X	X	X		X	[50]

Challenges included in the study X : challenges not included in the study.

The above table investigates the challenges present in the therapeutic applications of the Biofabricated SeNPs, like the unstable NP size, polydispersity, etc. From the above table, it was shown that the research studies by Mervat, et al., [49] and Xiaona, et al., [50] exhibited high potential with a lower number of challenges and limitations. On the other side, the research studies presented by Rasha and Neihaya [43] and Marjorie, et al., [44] demonstrated low performance with high challenges. Further, the studies published by the authors Wei, et al., [46], Zhangqian, et al., [47], and Mervat, et al., [49] were found to have advanced potential without the particle instability issues.

REVIEW SUMMARY

Most of the research focused on the chemically synthesized or the elemental forms of Se, despite various studies on the Biofabricated SeNPs. This elemental Se often posed toxicity concerns and limited biocompatibility. There is a notable gap in understanding the full therapeutic potential of the Biofabricated SeNPs. Existing studies lacked standardized protocols for the BF, detailed toxicity profiling, and long-term in vivo studies. Furthermore, only a few studies had explored the scalability, reproducibility, and BF of these eco-friendly SeNPs, which limited their integration into therapeutic applications, especially in AM, AO, and AC therapies. Also, the elemental Se often provided limitations, such as high cytotoxicity and poor bioavailability. The Biofabricated SeNPs had emerged as the solution to the toxicity concerns and the environmental concerns. The Biofabricated SeNPs offered a safe alternative; yet, the therapeutic benefits were underexplored, and the significant barriers like biological source variability, limited clinical validation, etc., remain unsolved. These limitations affected the acceptance of the Biofabricated SeNPs in modern biotechnology. The primary objective was to bridge the gap between the elemental Se and the BIOFABRICATED SeNPs. First, the dependence of diverse biological sources caused variability in the NP characteristics, affecting the reproducibility, and secondly, there was a lack of comprehensive regulatory guidelines for evaluating the safety and effectiveness of the Biofabricated SeNPs. Lastly, the current research lacked longitudinal clinical studies, affecting the transition of Biofabricated SeNPs from the experimental models to the real-world therapeutic applications. As previously explained in Section 2, research articles were extracted from the database between 2016 and 2025. Also, the research articles were organized according to the PRISMA

methodology. The graphical representation of the reviewed articles' selection results is exhibited in Figure 2.

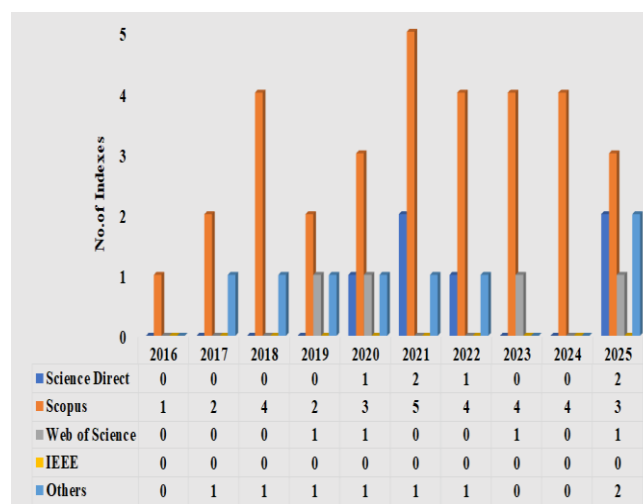


Figure 2: Graphical representation of the selection results of the reviewed articles

CONCLUSION

Here, this review focused on Biofabricated SeNPs and their therapeutic potential, and bridging the gap between elemental Se and Biofabricated SeNPs. By using the biological extracts like plants, fungi, microbes, etc, the study highlighted the therapeutic potential of the Biofabricated SeNPs. This offered enhanced bioavailability, improved biological activity, and a significant reduction of toxicity compared to the conventional elemental Se. As per the key findings from the study, the Biofabricated SeNPs exhibited promising therapeutic applications, particularly in the AM, AC, and AO treatments. Furthermore, the eco-friendliness of the synthesis methods, combined with the low cytotoxicity and high effectiveness, made the Biofabricated SeNPs suitable for safe clinical use. Also, the importance of the findings lay in the potential to advance safer, more effective therapeutic agents while addressing the limitations of the elemental Se. Nevertheless, the Biofabricated SeNPs had some limitations, like the variability in biological data, insufficient long-term clinical data, etc. Eventually, future research should focus on optimizing the synthesis methods, involving clinical trials, and optimizing the size variability in the particles, etc., for effective evaluation of safety and therapeutic outcomes of the Biofabricated SeNPs in real-world biomedical applications.

ACKNOWLEDGEMENTS:

The authors are thankful to R&D wing of Lalata Technologies (www.lalatastechnologies.com) for continuous support in article processing towards publication.

REFERENCE

1. Vasanthakumar S, Manikandan M and Muthu Arumugam, "Green synthesis, characterization and functional validation of bio-transformed selenium nanoparticles", *Biochemistry and Biophysics Reports*, vol. 39, pp. 1-9, 2024.
2. Anmol, Tejo Prakash N, Hisaaki Mihara and Ranjana Prakash, "Eco-Friendly Synthesis and Biomedical Applications of Exopolysaccharide-Capped Selenium Nanoparticles: Antimicrobial, Antioxidant, and Therapeutic Insights", *Proceedings of 8 th International Conference on Selenium in the Environment and Human Health* 6-9 July, Selenium in the Environment and Human Health, 2025, Chuzhou, China, 2025. <https://www.seleniumresearch.net/static/skin/Proceedings-of-8th-International-Conference-on-Selenium-in-the-Environment-and-Human-Health.pdf#page=60>
3. Feng Chen, Xiao Hong Zhang, Xiao Dan Hu, Pei Dang Liu and Hai Qian Zhang, "The effects of combined selenium nanoparticles and radiation therapy on breast cancer cells in vitro", *Artificial Cells, Nanomedicine, and Biotechnology*, vol. 46, no. 5, pp. 1-13, 2018.
4. Yu Xia, Mingqi Zhao, Yi Chen, Liang Hua, Tiantian Xu, Changbing Wang, Yinghua Li and Bing Zhu, "Folate-targeted selenium nanoparticles deliver therapeutic siRNA to improve hepatocellular carcinoma therapy", *RSC Advances*, vol. 8, pp. 1-9, 2018.
5. Gafar Babatunde Bamigbade, Athira Subhash, Mohammed Abdin, Hebah Jarusheh, Basim Abu-Jdayil, Shao-Quan Liu, Giovanni Palmisano, Abdelmoneim Ali, Afaf Kamal Eldin and Mutamed Ayyash, "Date pomace polysaccharides-capped selenium nanoparticles: Biosynthesis, optimization, physicochemical characterization, biological activities, stability and gut microbiota modulation", *Food Hydrocolloids for Health*, vol. 7, pp. 1-20, 2025.
6. Salem S. Salem, "Biofabrication of Selenium Nanoparticles Using Baker's Yeast Extract and Its Antimicrobial Efcacy on Food Borne Pathogens", *Applied Biochemistry and Biotechnology*, vol. 194, pp. 1-13, 2022.
7. Venkatesan Alagesan and Sujatha Venugopal, "Green Synthesis of Selenium Nanoparticle Using Leaves Extract of *Withania somnifera* and Its Biological Applications and Photocatalytic Activities", *BioNanoScience*, vol. 9, pp. 1-12, 2019.
8. Jyotsna Setty, Sanjib Bal Samant, Mayank KumarYadav, Manjubala Mand Vijai Pandurangam, "Benefcial effects of BIOFABRICATED selenium nanoparticles as seed nanoprimer agent on seed germination in rice (*Oryza sativa* L.)", *Scientific Reports*, vol. 13, pp. 1-14, 2023.
9. Abir Das, Sayan Pal, Mirza Hasanuzzaman, Malay Kumar Adak and Sudipta Kumar Sil, "Mitigation of aluminum toxicity in rice seedlings using Biofabricated selenium nanoparticles and nitric oxide: Synergistic effects on oxidative stress tolerance and sulfur metabolism", *Chemosphere*, vol. 370, pp. 1-13, 2025.
10. Muhammad Ikram, Naveed Iqbal Raja, Bilal Javed, Zia-ur-Rehman Mashwani, Mubashir Hussain, Mujahid Hussain, Maria Ehsan, Noman Rafique, Khafsa Malik, Tahira Sultana, and Abida Akram, "Foliar applications of BIOFABRICATED selenium nanoparticles to improve the growth of wheat plants under drought stress", *Green Processing and Synthesis*, vol. 9, pp. 1-9, 2020.
11. Chinnaraj Santhosh, Balamuralikrishnan Balasubramanian, Palani Vino, Maluventhen Viji, Chandrababu Rejeeth, Soundarapandian Kannan, Hammad Ullah, Kannan R.R. Rengasamy, Maria Daglia and Arumugam Maruthupandian, "Biofabricated selenium nanoparticles mediated from *Goniothalamus wightii* gains biomedical applications and photocatalytic degrading ability", *Journal of King Saud University – Science*, vol. 34, pp. 1-9, 2022.
12. Mohamed K. Y. Soliman and Salem S. Salem, "Uncovering the potential of Biofabricated Ananas comosus peel selenium nanoparticles for antibacterial, antibiofilm, suppression of virulence genes (can and LuxS), anticancer, and antioxidant properties", *BMC Biotechnology*, vol. 25, pp. 1-21, 2025.
13. Lucas Marcelino dos Santos Souza, Miriam Dibo, Juan Josue Puno Sarmiento, Amedea Barozzi Seabra, Leonardo Pinto Medeiros, Isabella Martins Lourenço, Renata Katsuko Takayama Kobayashi and Gerson Nakazato, "Biosynthesis of selenium nanoparticles using combinations of plant extracts and their antibacterial activity", *Current Research in Green and Sustainable Chemistry*, vol. 5, pp. 1-10, 2022.
14. Chen Chen, Fructueux Modeste Amona, Ziqi Sha, Jiamin Li, Yongding Ke, Yuxin You, Luyuan Yang, Guangfu Liao, Xi Chen, Yipeng Pang and Yi Liu, "Green synthesis of purple sweet potato-derived selenium nanoparticles accelerates wound healing through pyroptosis regulation", *Materials Today Bio*, vol. 35, pp. 1-15, 2025.
15. Jay Vyas and Shafkat Rana, "Antioxidant Activity And Biogenic Synthesis Of Selenium Nanoparticles Using The Leaf Extract Of Aloe Vera", *International Journal of Current Pharmaceutical Research*, vol. 9, no. 4, pp. 1-6, 2017.
16. Salem S. Salem, Moustafa M. G. Fouda, Amr

- Fouda, Mohamed A. Awad, Ebtesam M. Al-Olayan, Ahmed A. Allam and Tharwat I. Shaheen, "Antibacterial, Cytotoxicity and Larvicidal Activity of Green Synthesized Selenium Nanoparticles Using *Penicillium corylophilum*", *Journal of Cluster Science*, vol. 32, pp. 1-12, 2021.
17. Amr Hosny Hashem, Ahmed Mohamed Aly Khalil, Ahmed M. Reyad and Salem S Salem, "Biomedical Applications of Mycosynthesized Selenium Nanoparticles Using *Penicillium expansum* ATTC 36200", *Biological Trace Element Research*, pp. 1-11, 2021. <https://doi.org/10.1007/s12011-020-02506-z>
18. Bilang Cao, Yueling Yang, Chunhua Yue, Yuanyuan Wang, Pengcheng Fu and Yongguang Bi, "Preparation, Characteristics, and Antioxidant Activity of the Selenium Nanoparticles Stabilized by Polysaccharides Isolated from *Grateloupia filicina*", *Grateloupia filicina*. *Phcog Mag*, vol. 16, pp. 1-7, 2020.
19. Natwar Jhaa, Palanichamy Esakkiraj, Asaikkutti Annamalai, Avinash Kant Lakraa, Sanjay Naik and Venkatesan Arul, "Synthesis, optimization, and physicochemical characterization of selenium nanoparticles from polysaccharide of mangrove *Rhizophora mucronata* with potential bioactivities", *Journal of Trace Elements and Minerals*, vol. 2, pp. 2-14, 2022.
20. Fatemeh Nazarzadeh, Saied Navabpour, Zahra Sabouri and Majid Darroudi, "Eco-friendly synthesis of selenium nanoparticles using *Cuminum cyminum* L extract: Evaluating their cytotoxicity, antimicrobial properties, and photocatalytic efficiency", *Open Ceramics*, vol. 23, pp. 1-7, 2025.
21. Heba S. Abbas, Doha H. Abou Baker and Entesar A. Ahmed, "Cytotoxicity and antimicrobial efficiency of selenium nanoparticles biosynthesized by *Spirulina platensis*", *Archives of Microbiology*, vol. 203, no.2, pp. 1-10, 2020.
22. Kehinde Sowunmi, Oladosu Micheal Abimbola, Moses Adondua Abah et al., "Green Synthesis, Photo-Physical Characterization, and Evaluation of in-vitro Antioxidant, AntiInflammatory, and Antidiabetic Properties of Selenium Nanoparticles Derived from *Nigella Sativa* seeds", *Journal of Nanomedicine*, vol. 8, no. 1, pp. 1-6, 2025.
23. Safieh Boroumand, Mojdeh Safari, Elnaz Shaabani, Mahdieh Shirzad and Reza Faridi-Majidi, "Selenium nanoparticles: synthesis, characterization and study of their cytotoxicity, antioxidant and antibacterial activity", *Materials Research Express*, vol. 6, no. 8, pp. 1-18, 2019.
24. Nahid Shahabadi, Saba Zendehecheshm and Fatemeh Khademic, "Selenium nanoparticles: Synthesis, in-vitro cytotoxicity, antioxidant activity and interaction studies with ct-DNA and HSA, Hb and Cyt c serum proteins", *Biotechnology Reports*, vol. 30, pp. 1-21, 2021.
25. Anna V. Tugarova, Polina V. Mamchenkova, Yulia A. Dyatlova and Alexander A. Kamnev, "FTIR and Raman spectroscopic studies of selenium nanoparticles synthesised by the bacterium *Azospirillum thiophilum*", *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, vol. 192, pp. 1-20, 2017.
26. Ehsan H. Abu-Zeid, Doaaa M. Abdel Fattah, Ahmed H. Arisha, Tamer A. Ismail, Dina M. Alsadek, Mohamed M.M. Metwally, Ahmed A. El-Sayed and Amany T. Khalil, "Protective prospects of eco-friendly synthesized selenium nanoparticles using *Moringa oleifera* or *Moringa oleifera* leaf extract against melamine induced nephrotoxicity in male rats", *Ecotoxicology and Environmental Safety*, vol. 221, pp. 1-13, 2021.
27. Gbemisola Elizabeth Ogunleye, Kubrat Abiola Oyinlola, Oluwadurotimi Akintade, Rachel Fashogbon and Temiloluwa Adesina, "Green synthesis, Characterization and Antimicrobial potential of Selenium Nanoparticles from *Ocimum gratissimum*", *Turkish Journal of Agriculture - Food Science and Technology*, vol. 10, pp. 1-10, 2022.
28. Madhumitha.B, Preetha Santhakumar, M. Jeevitha and S. Rajeshkumar, "Green Synthesis of Selenium Nanoparticle using *Capparis decidua* fruit extract and its Characterization using Transmission Electron Microscopy And UV- Visible Spectroscopy", *Research Journal of Pharmacy and Technology*, vol. 14, no. 4, pp.1-1, 2021.
29. Thirumalaivasan Ramachandran, Devaprakash Manoharan, Sivakumar Natesan, Shyam Kumar Rajaram, Ponmurugan Karuppiah, Mohammed Rafi Shaik, Mujeeb Khan and Baji Shaik, "Synthesis and Structural Characterization of Selenium Nanoparticles–*Bacillus* sp. MKUST-01 Exopolysaccharide (SeNPs–EPS) Conjugate for Biomedical Applications", *Biomedicines*, vol. 11, pp. 1-18, 2023.
30. Aruna Jyothi Kora and Lori Rastogi, "Biomimetic synthesis of selenium nanoparticles by *Pseudomonas aeruginosa* ATCC 27853: An approach for conversion of selenite", *Journal of Environmental Management*, vol. 181, pp. 1-6, 2016.
31. Greeshma B.C and M. Mahesh, "Biosynthesis of selenium nanoparticles from *Bacillus* species and its applications", *Journal of Applied and Natural Science*, vol. 11, no. 4, pp. 1-6, 2019.
32. Pei Liu, Haiyu Long, Han Cheng et al., "Highly-efficient synthesis of biogenic selenium nanoparticles by *Bacillus paramycooides* and their antibacterial and antioxidant activities", *Frontiers in Bioengineering and Biotechnology*, vol. 11, pp. 1-14, 2023.
33. Suseenthar Ramya, Thangavel Shanmugasundaram and Ramasamy Balagurunathan, "Actinobacterial enzyme mediated synthesis of selenium

- nanoparticles for antibacterial, mosquito larvicidal and anthelmintic applications”, *Particulate Science and Technology*, vol. 38, no. 1, pp. 1-11, 2019.
34. Ashraf Al-Brakati, Khalaf F Alsharif, Khalid J Alzahrani et al., “Using Green Biosynthesized Lycopene-Coated Selenium Nanoparticles to Rescue Renal Damage in Glycerol-Induced Acute Kidney Injury in Rats”, *International Journal of Nanomedicine*, vol. 16, pp. 1-16, 2021.
35. Neeraj Kumar, K.K. Krishnani, Sanjay Kumar Gupta, Rupam Sharma, Raju Baitha, Dilip Kumar Singh and Narendra Pratap Singh, “Immuno-protective role of biologically synthesized dietary selenium nanoparticles against multiple stressors in *Pangasinodon hypophthalmus*”, *Fish and Shellfish Immunology*, vol. 78, pp. 1-33, 2018.
36. Manisha Kumari, Mahaveer Prasad Purohit, Satyakam Patnaik, Yogeshwer Shukla, Pradeep Kumar and Kailash Chand Gupta, “Curcumin loaded selenium nanoparticles synergize the anticancer potential of doxorubicin contained in self-assembled, cell receptor targeted nanoparticles”, *European Journal of Pharmaceutics and Biopharmaceutics*, vol. 138, pp. 1-44, 2018.
37. Bushra Afzal, Durdana Yasin, Haleema Naaz, Neha Sami, Almaz Zaki, Moshahid Alam Rizvi, Raj Kumar, Pooja Srivastava and Tasneem Fatma, “Biomedical potential of *Anabaena variabilis* NCCU441 based Selenium nanoparticles and their comparison with commercial nanoparticles”, *Scientific Reports*, vol. 11, pp. 1-15, 2021.
38. Amira A. El-Fallal, Mohamed I. Abou-Dobara, Ahmed K. El-Sayed, Mayada F. El-Fawal and Mohamed M. El-Zahed, “Green synthesis, Optimization and Antifungal Activity of Selenium nanoparticles using *Fusarium fujikuroi* MED14”, *Scientific Journal for Damietta Faculty of Science*, vol. 14, no. 3, pp. 1-9, 2024.
39. Guifang Gong, Bailing Fu, Caixin Ying et al., “Targeted delivery of paclitaxel by functionalized selenium nanoparticles for anticancer therapy through ROS-mediated signaling pathways”, *Royal Society of Chemistry*, vol. 8, pp. 1-10, 2018.
40. Yidong Xiao, Qilin Huang, Zhaomin Zheng, Han Guan and Shiyu Liu, “Construction of a *Cordyceps sinensis* exopolysaccharide-conjugated selenium nanoparticles and enhancement of their antioxidant activities”, *International Journal of Biological Macromolecules*, vol. 99, pp. 1-9, 2017.
41. Ghader Habibi and Yahya Aleyasin, “Green synthesis of Se nanoparticles and its effect on salt tolerance of barley plants”, *International Journal of Nano Dimension*, vol. 11, no. 2, pp. 1-13, 2020.
42. Ishita Matai, Satish Kumar Pandey, Deepa Garg, Komal Rani and Abhay Sachdev, “Phytogreen synthesis of multifunctional nano selenium with antibacterial and antioxidant implications”, *Nano Express*, vol. 1, no. 1, pp. 1-14, 2020.
43. Rasha Muhsin Yasir and Neihaya Heikmat Zaki, “Antioxidant and Anticancer Activities of Bio-Synthesized Selenium Nanoparticles by *Escherichia coli*”, *Biological Activities of Biosynthesized SeNPs*, vol. 26, pp. 1-9, 2025.
44. Marjorie C. Zambonino, Ernesto Mateo Quizhpe, Lynda Mouheb, Ashiqur Rahman, Spiros N. Agathos and Si Amar Dahoumane, “Biogenic Selenium Nanoparticles in Biomedical Sciences: Properties, Current Trends, Novel Opportunities and Emerging Challenges in Theranostic Nanomedicine”, *Nanomaterials*, vol. 13, pp. 1-70, 2023.
45. Maryam Tabibi, Soheil Aghaei, Mohammad Ali Amoozegar, Raziieh Nazari and Mohammad Reza Zolfaghari, “Characterization of green synthesized selenium nanoparticles (SeNPs) in two different indigenous halophilic bacteria”, *BMC Chemistry*, vol. 17, no. 1, pp. 1-12, 2023.
46. Wei He, Xin Tian, Quan Zhou et al., “Selenium nanoparticles ameliorate lumbar disc degeneration by restoring GPX1-mediated redox homeostasis and mitochondrial function of nucleus pulposus cells”, *Journal of Nanobiotechnology*, vol. 22, no. 1, pp. 1-23, 2024.
47. Zhangqian Wang, Nana Li, Xin Zhou et al., “Optimization of fermentation parameters to improve the biosynthesis of selenium nanoparticles by *Bacillus licheniformis* F1 and its comprehensive application”, *BMC Microbiology*, vol. 24, pp. 1-18, 2024.
48. Jiaojiao Zhou, Die Zhang, Xuqin Lv, Xiaoqing Liu, Wei Xu, Lei Chen, Jie Cai, Zia-ud Din and Shuiyuan Cheng, “Green Synthesis of Robust Selenium Nanoparticles via Polysaccharide–Polyphenol Interaction: Design Principles and Structure–Bioactivity Relationship”, *ACS Sustainable Chemistry and Engineering*, vol. 10, pp. 1-11, 2022.
49. Mervat G. Hassan, Mariam T. Hawwa, Dina M. Baraka, Hamed M. ElShora and Ahmed A. Hamed, “Biogenic selenium nanoparticles and selenium/chitosan-Nanoconjugate biosynthesized by *Streptomyces parvulus* MAR4 with antimicrobial and anticancer potential”, *BMC Microbiology*, vol. 21, pp. 1-18, 2024.
50. Xiaona Yuan, Zhenshuai Fu, Pengfei Ji, Lubo Guo, Ali O Al-Ghamdy, Ali Alkandiri, Ola A Habotta, Ahmed E Abdel Moneim and Rami B Kassab, “Selenium Nanoparticles Pre-Treatment Reverse Behavioral, Oxidative Damage, Neuronal Loss and Neurochemical Alterations in Pentylene-tetrazole -Induced Epileptic Seizures in Mice”, *International Journal of Nanomedicine*, vol. 15, pp. 1-16, 2020.