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An Overview on Selenium Species Bioconversion by Bacteria from Mangrove, Red Sea, Egypt and Its Applications

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ABSTRACT

Selenium is an essential trace element that is fundamental for life at low concentrations but becomes hazardous at slightly higher levels. It is widely distributed in the environment, including soil, water, plants, wastewater, mining sites, and the atmosphere. The conversion of selenite into elemental selenium has attracted significant attention because of its wide range of applications, unique properties, and the toxicity concerns associated with conventional chemical methods. As a result, green synthesis, or environmentally friendly alternatives, is increasingly emphasized. To effectively reduce selenite into elemental selenium, the isolation and characterization of halophilic selenite-reducing bacterial strains from the unique mangrove ecosystems of the Red Sea are crucial. Understanding the genetic diversity of these strains is essential, as genetic variation influences their metabolic capabilities and selenite reduction efficiency. Modern molecular techniques—such as DNA sequencing and proteomic analysis—offer powerful tools for assessing biodiversity at both genotypic and phenotypic levels, enabling precise identification of functional genes and pathways involved in selenite biotransformation. This research focused on how microorganisms convert inorganic selenium into less hazardous organic forms. It also investigated the biosynthesis and mechanisms of selenium nanoparticles (BioSeNPs), highlighting their diverse medicinal and environmental applications, including antibacterial, antiviral, anticancer, antioxidant, anti-inflammatory, agricultural uses, and heavy metal remediation. The study ultimately aimed to identify and develop bacterial strains with enhanced ability to convert and accumulate selenium, contributing to the production of safer and more effective selenium-based products.

INTRODUCTION

In 1817, Swedish scientist Jöns Jakob Berzelius was the first to discover selenium (Se), whose chemical properties closely resemble those of sulfur **(Fordyce, 2007)**. Selenium occurs in several forms: water-soluble selenate (SeO_4^{2-}) and selenite (SeO_3^{2-}), water-insoluble elemental selenium (Se^0), unstable selenide (Se^{2-}), and organic forms such as selenocysteine and selenomethionine. It can also exist in multiple oxidation states (+2, 0, +4, and +6) **(Pandey *et al*., 2021)**.

The most toxic forms are selenate and selenite, which are both highly soluble and bioavailable **(Wang *et al*., 2018)**. Selenium is an essential trace element that is incorporated into selenoproteins in the form of selenocysteine, a key component of their active core **(Khurana *et al*., 2019)**. Selenium plays several roles in living organisms, including supporting physiological metabolic processes. Although humans and animals require only trace amounts, selenium is vital for cellular functions such as tissue respiration, thyroid hormone regulation, and antioxidant defense **(Preda *et al*., 2017; Titov *et al*., 2022)**.

The chemical form of selenium strongly influences its bioavailability. Inorganic selenium is often poorly absorbed and rapidly degraded, whereas organic selenium is less toxic, more bioavailable, and remains longer in both humans and animals. It is estimated to be about seven times more effective than inorganic selenium **(Jäger *et al*., 2016; Kim & Kil, 2020; Hadrup & Ravn-Haren, 2021; Jiang *et al*., 2021)**.

Harnessing the unique metabolic pathways and adaptation mechanisms of halophilic and halotolerant bacteria represents a promising strategy for safe and efficient selenium biotransformation. These bacteria not only reduce toxic selenium to less harmful elemental selenium via biomineralization but also produce valuable compounds, including extracellular hydrolytic enzymes with applications in chemical and medical sciences **(Ventosa & Ventosa, 2004; Chen & Liu, 2013; Shatla *et al*., 2021)**.

The mangrove ecosystem of the Red Sea hosts a wide diversity of marine species that have been studied for centuries, yet its microbial richness remains largely unexplored. In many ecosystems, biodiversity levels are shifting at unknown rates, further emphasizing the importance of investigating unique environments such as mangroves **(Hoegh-Guldberg *et al*., 2007)**.

This review explores microbial transformation of selenite into elemental selenium, focusing on halophilic bacteria isolated from the Red Sea mangrove ecosystems in Egypt. It highlights mechanisms of selenite reduction, the role of genetic and protein-based diversity, and the applications of selenium nanoparticles in medicine, agriculture, and environmental remediation. The objective was to synthesize current knowledge, identify gaps, and propose directions for future research.

1. Selenium

Selenium occurs in the environment in various chemical forms. Soluble forms such as selenate (SeO_4^{2-}) and selenite (SeO_3^{2-}) are highly bioavailable but toxic at elevated concentrations, whereas elemental selenium (Se^0) and selenides are less soluble and less bioavailable. Thus, the bioaccessibility and toxicity of selenium strongly depend on its chemical form **(Pandey *et al*., 2021)**.

To balance environmental exposure and health requirements, selenium intake must be carefully regulated. It is considered toxic at dietary levels > 400µg/ day and deficient at < 40µg/ day **(Fordyce, 2007)**. In both natural and industrial environments, Se^0 plays a central role in the selenium biogeochemical cycle **(Staicu & Barton, 2021)**.

With a concentration of about 50 parts per billion, selenium ranks as the 67th most abundant element in Earth's crust. It has an atomic number of 34, belongs to period 4 and group 16, and has the electron configuration [Ar] $4s^2\ 3d^{10}\ 4p^4$ **(Mehdi *et al*., 2013)**. Selenium is released into the environment through natural processes such as weathering of ores, volcanic activity, and erosion of soils and sedimentary rocks **(Khoei *et al*., 2017)**. Human activities, including oil combustion, metal extraction, and industrial or agricultural production, have further increased selenium fluxes in soil and water, raising the risk of its entry into the food chain **(Etteieb *et al*., 2020)**.

The most abundant natural isotope of selenium is ^{80}Se (49.82%), while the least common is ^{77}Se (7.58%). It has a melting point of 220.5°C and a boiling point of 685°C. Selenium is a chalcogen and shares chemical similarities with sulfur in terms of oxidation states, atomic size, ionization potential, and bond energies. It can also combine with hydrogen, phosphorus, chlorine, fluorine, and bromine to form compounds similar to those of sulfur **(Charya, 2016)**.

2. Microbial reduction of selenium oxyanions

The mechanisms of selenate and selenite dissimilatory reduction vary among bacterial species and even within the same microorganism. Selenium nanoparticles (SeNPs), which can form under both anaerobic and aerobic conditions, are the primary products of dissimilatory reduction of selenate and selenite **(Nancharaiah & Lens, 2015)**.

The reduction of SeO_4^{2-} to SeO_3^{2-} is primarily catalyzed by selenium reductase (Ser), an enzyme that may be soluble or membrane-bound **(Schröder *et al*., 1997; Kuroda *et al*., 2011)**. Ser typically consists of three subunits and requires molybdenum as a cofactor. It is located either on the cytoplasmic membrane or in the periplasm. Only a limited number of microorganisms have been identified in pure culture that utilize selenium species (SeO_4^{2-}, SeO_3^{2-}, or Se^0) as terminal electron acceptors during anaerobic respiration, as illustrated in Fig. (2). The microbial reduction of selenate (SeO_4^{2-}) converts SeO_4^{2-} into the stable elemental selenium (Se^0) species. Gram-positive and Gram-negative bacteria release the product, SeO_3^{2-}, outside the cytoplasmic membrane or in the periplasm, respectively **(Nancharaiah & Lens, 2015)**, as shown in Equation 1:

SeO_4^{2-} (aq) ⟶ SeO_3^{2-} (aq) ⟶ Se^0 (s) ⟶ HSe^- (aq) (1)

However, since glutathione is known to be exported to the periplasm via ABC-type transporters, selenite reduction in the periplasm or on the cell membrane cannot be disregarded, or through the recently identified detoxification process of periplasmic fumarate reductase. Microorganisms are rich in reduced thiols like glutathione and glutaredoxin, which frequently promote selenite reduction (SeO_3^{2-}) in the cytoplasm. Furthermore, SeO_3^{2-} reduction is catalyzed by anaerobic respiration terminal reductases, like fumarate, sulfite, and nitrite reductase **(Pittman *et al.*, 2005; Stolz *et al.*, 2006; Li *et al.*, 2014)**.

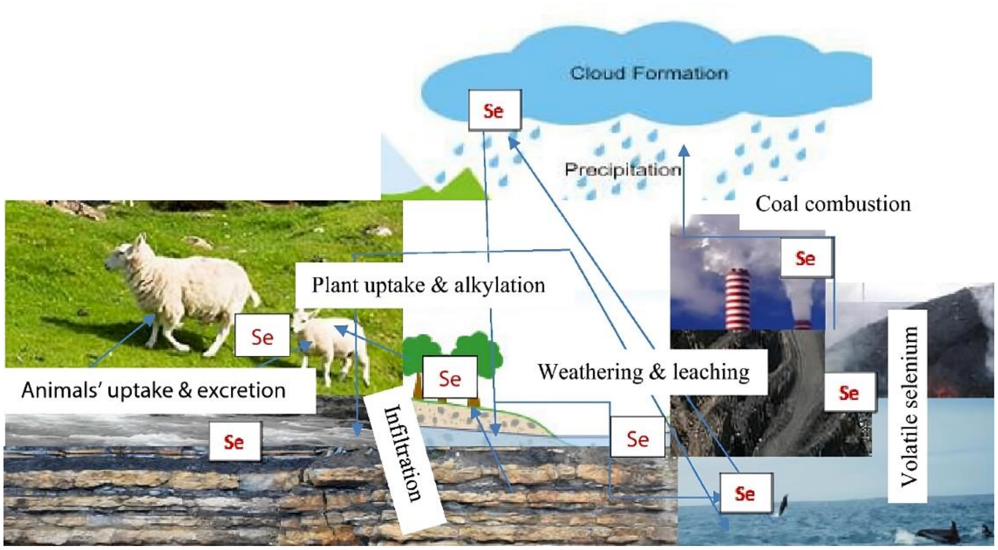

Fig. 1. Environmental pathways and biogeochemical cycling of selenium (Se) from natural and anthropogenic sources **(Gebreeyessus & Zewge, 2019)**

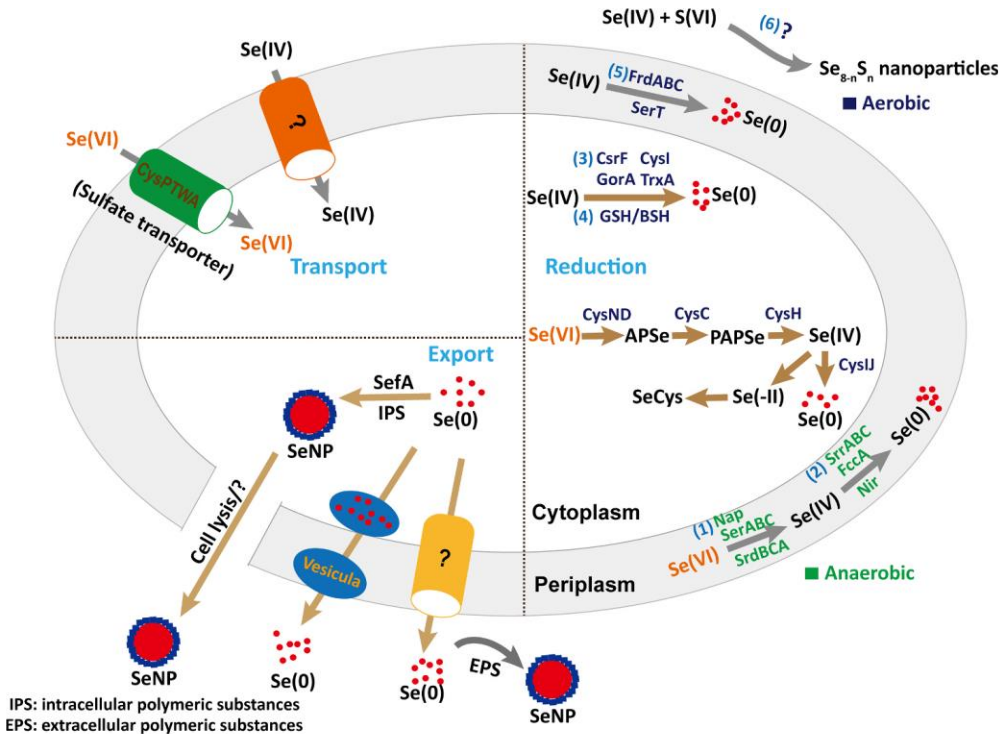

Fig. 2. Schematic representation of microbial transport, intracellular reduction, and export mechanisms of selenium oxyanions, highlighting Se^0 nanoparticle formation under aerobic and anaerobic conditions **(Wang *et al*., 2022)**

1. **Bioconversion of selenium species by microorganisms**

Many microorganisms, including *Shewanella oneidensis* MR-1, *Pseudomonas stutzeri* TS44, *Ochrobactrum* sp., and certain yeast species, are capable of converting various chemical forms of selenium. These organisms play an essential role in recycling selenium and reducing its toxicity **(Dungan & Frankenberger, 1999)**.

Several bacterial species have been reported to reduce selenite to elemental selenium (Se^0) under both aerobic and anaerobic conditions **(Bebien *et al*., 2001; Klonowska *et al*., 2005)**. These microbial processes—demethylation, oxidation, methylation, and reduction—can generate selenium compounds beneficial for both nutrition and technology. For most microorganisms, the preferred pathways are the dissimilatory reduction of selenium oxyanions and methylation of the resulting products **(Eswayah *et al*., 2016)**.

2. Assay for selenite reduction

The first indication of elemental selenium (Se^0) synthesis was a visible color change in the culture medium, which turned red, pink, or orange. This color shift indicated the isolates' ability to convert selenite into elemental selenium on salt peptone agar (SPA) containing (g/L): KCl, 0.5; $MgSO_4·7H_2O$, 1.0; $CaCl_2·3H_2O$, 0.7; $MnCl_2·4H_2O$, 0.05; peptone, 10.0; yeast extract, 10.0; and agar, 15.0. Nutrient broth (NB) medium was also supplemented with 5 mM sodium selenite and 5% NaCl (w/v), adjusted to pH 7.0 ± 0.2. The cultures were incubated at 30 °C under aerobic conditions for 72 hours in the presence of sodium selenite **(Shatla *et al*., 2021)** (Fig. 3).

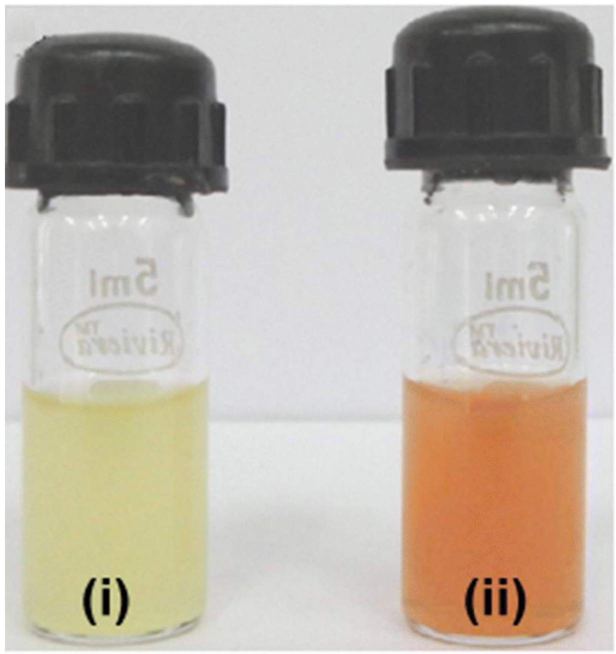

Fig. 3. (i) Colorless colonies in absence of sodium selenite, the formation of red colonies in presence of sodium selenite, **(ii) (Kora, 2018)**

3. Selenite-reducing bacteria (SRB) ecology

Selenium-respiring bacteria have been isolated from diverse environmental sources, including virgin and contaminated soils and waters from various geographical regions **(Nancharaiah & Lens, 2015)**. Among these, marine and hypersaline environments represent unique ecological niches that support the growth of halophilic, selenite-reducing bacteria. These halophiles differ significantly from non-halophilic bacteria in their metabolic characteristics due to high salt concentrations and low water activity. Consequently, halophilic microorganisms produce a variety of valuable metabolites, including biosurfactants, hydrolytic enzymes, biofuels, biopolymers, and compatible solutes **(Oren, 2010)**.

Because halophilic prokaryotes require salt for survival—particularly sodium chloride—they cannot live without it **(Abdollahnia *et al*., 2020)**. Based on their sodium chloride requirement, microorganisms are classified as:

- **Extreme halophiles:** thrive at ~25% NaCl (w/v)
- **Moderate halophiles:** thrive at 3–15% NaCl (w/v)

- **Slight halophiles:** thrive at ~3% NaCl (w/v) **(Irshad *et al*., 2014)**

Research into the use of moderately halophilic bacteria for nanoparticle (NP) biosynthesis and applications is still in its early stages **(Abdollahnia *et al*., 2020)**. Nevertheless, selenium nanoparticles (SeNPs) synthesized by these bacteria have demonstrated antibacterial and anti-biofilm properties **(Selvaraj *et al*., 2023)**.

Mangrove ecosystems, which are intertidal wetlands located at the land–sea interface, are well known for their rich microbial diversity **(Shatla *et al*., 2021)**. In addition to playing a vital ecological role, mangrove-associated microorganisms produce a wide variety of bioactive metabolites **(Bharathkumar *et al*., 2008)**. In this study, moderately halophilic bacteria isolated from mangrove habitats along the Red Sea coast of Egypt were investigated for their ability to produce SeNPs **(Selvaraj *et al*., 2023)**.

Potential molecular and protein-based approaches for studying the diversity of selenite-reducing bacteria

Various molecular and biochemical techniques have been widely employed to assess genetic and protein diversity in bacterial species. Among them:

Amplified fragment length polymorphism (AFLP)

These markers are highly effective tools for detecting extensive polymorphism, allowing for precise and detailed genetic analyses **(Siracusa *et al.*, 2013; Al-Hadeithi & Jasim, 2021)**

Simple sequence repeat (SSR), and inter simple sequence repeat (ISSR)

They have been developed for studying genetic diversity, fingerprinting, and mapping, and have proven effective in distinguishing between closely related species **(Lax *et al*., 2007; Zheng *et al*., 2013)**. The widespread use of inter-simple sequence repeats (ISSRs) is attributed to their ability to amplify DNA regions between two microsatellites. Since ISSRs can be generated without prior sequence information, they are useful for evaluating the selectivity of microsatellite markers while employing random markers.

ISSR primers are powerful molecular markers capable of differentiating among cultivars due to their high variability in resolving power (Rp), polymorphism, and band informativeness (Ib) **(Guasmi *et al*., 2012)**.

Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE)

Additionally, several techniques are commonly employed to study microbial diversity, including DNA analysis (molecular markers), biochemical protein analysis (SDS-PAGE, isozyme assays), agronomic evaluation, and qualitative and quantitative morphological analysis **(Agarwal *et al*., 2020)**. SDS-PAGE, in particular, provides reliable phenotypic evidence for evaluating similarities among bacterial strains within the same species **(Moore *et al*., 1980)**. Comparative studies across multiple bacterial genera have demonstrated a strong correlation between protein pattern similarity and genomic DNA homology, highlighting its effectiveness in supporting molecular identification and classification **(Goodfellow & O'Donnell, 1993)**.

Molecular weight estimation and protein separation have been among the primary applications of SDS-PAGE since the 1950s **(Hamdan & Righetti, 2005)**. In 1970, Laemmli introduced the most widely used SDS-PAGE protocol, which remains a standard today. Modern electrophoresis techniques vary in buffer composition and gel permeability depending on the size of the proteins to be separated **(Schägger, 2006)**. All SDS-PAGE methods rely on the ability of SDS to bind proteins, enabling size-based protein separation and analysis. For this reason, SDS-PAGE is regarded as a universal tool for protein characterization **(Pavlova *et al*., 2018)**.

Although these techniques have not yet been extensively applied to selenite-reducing bacteria, they represent promising approaches for future studies exploring both the genetic and phenotypic diversity of such isolates, particularly with respect to their selenium-reducing capabilities.

The effects of selenium's biological activity on human health

Although selenate (SeO_4^{2-}), selenite (SeO_3^{2-}), and organic selenium have been reported with their higher toxicity compared selenium nanoparticles (SeNPs), selenium has a narrow threshold between toxicity and therapeutic **(Wang *et al.*, 2007)**. Humans require Se as a micronutrient, and its levels in the body are influenced by environmental factors **(Rayman *et al.*, 2018)**.

Numerous studies have confirmed that biogenic selenium nanoparticles (SeNPs) possess antimicrobial **(Vaquette *et al.*, 2020)**, antioxidant **(Ge *et al.*, 2022)**, hormone secretion- promoting properties **(Ojeda *et al.*, 2022)**, and anticancer **(Wang *et al.*, 2022)**, as shown in Fig. (4).

Antibacterial activity

The biocidal properties of selenium nanoparticles are strongly influenced by their shape and size. Smaller nanoparticles (50– 100nm) with a spherical morphology are generally more effective than larger ones, as they can more easily penetrate bacterial cell membranes and disrupt cellular functions **(Al-Saggaf *et al*., 2020; dos Santos Souza *et al*., 2022)**. Selenium nanoparticles exhibit broad-spectrum antimicrobial activity against both Gram-positive and Gram-negative bacteria **(Al Jahdaly *et al*., 2021)**, as illustrated in Fig. (5).

Antifungal activity

One of the novel approaches to addressing this issue is the application of selenium nanoparticles (SeNPs). Their antifungal mechanism of action is similar to that observed in bacteria; due to their small size and high surface area-to-volume ratio, SeNPs interact closely with microbial cell membranes. These interactions—particularly with thiol (-SH) groups in membrane proteins—alter membrane permeability, facilitate intracellular diffusion, and ultimately cause substantial membrane damage. In addition, SeNPs exert lethal effects by damaging DNA, disrupting mitochondrial membranes, altering gene expression, and inhibiting cell proliferation through the generation of reactive oxygen species (ROS) **(Lazcano-Ramírez *et al*., 2023)**.

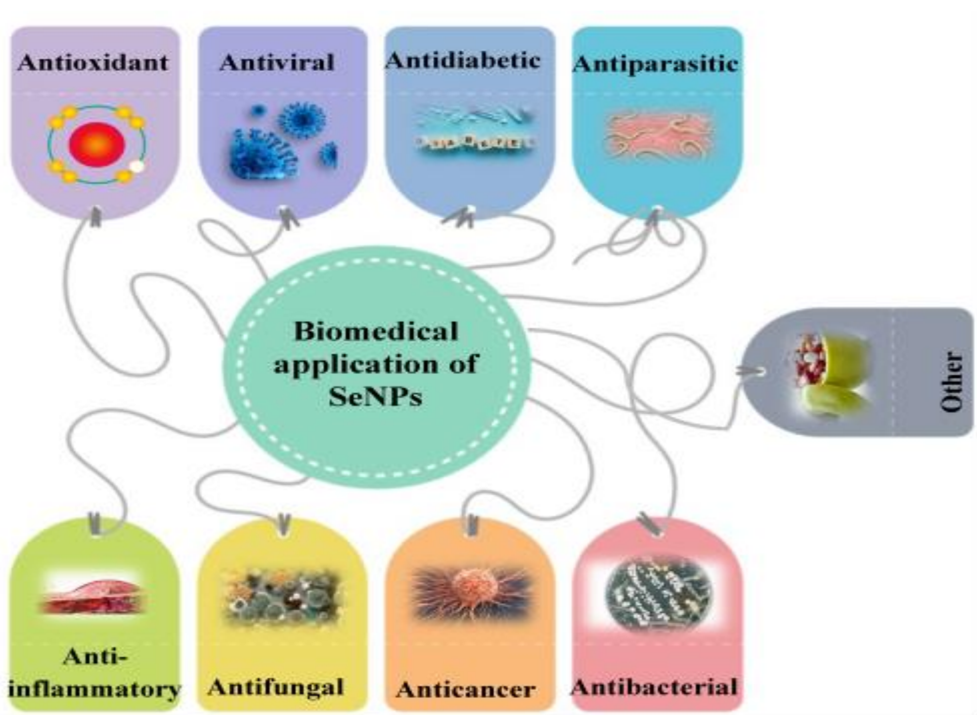

Fig. 4. Therapeutic and biomedical potentials of selenium nanoparticles (SeNPs) **(Mikhailova, 2023)**

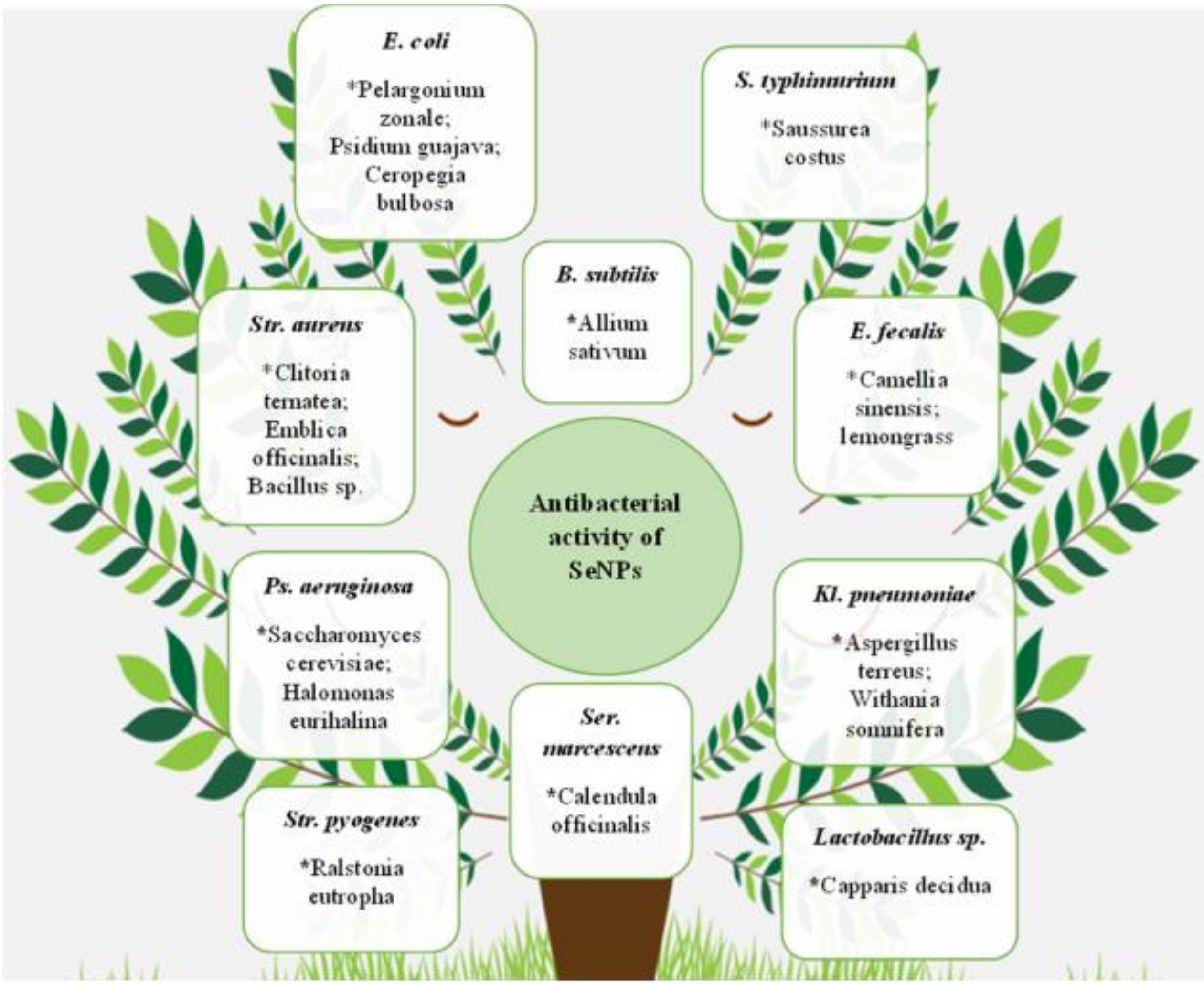

Fig. 5. Antibacterial activity of selenium nanoparticles (SeNPs) synthesized from various biological sources (indicated by *), against different pathogenic bacteria. **(Mikhailova, 2023)**

Antiviral

For the prevention or treatment of COVID-19, studies, including clinical trials, have investigated the potential of selenium supplementation, either as a nutritional supplement or as a monotherapy. The selenium anti-COVID-19 activity is attributed to its ability to reduce oxidative stress, block the 3CLPro (main protease) and PL pro enzymes of SARS-CoV-2, lower the expression of the ACE-2 receptor, and production of pro-inflammatory chemicals reduction **(Schomburg, 2021)**.

Anticancer

The most extensively studied anticancer mechanism of selenium nanoparticles (SeNPs) *in vitro* is apoptosis, characterized by membrane dysfunction, cytoplasmic shrinkage, and nuclear chromatin condensation. The primary cytotoxic effects of SeNPs are associated with oxidative stress and the generation of reactive oxygen species (ROS). ROS modulate the activity of key enzymes involved in cell death pathways, thereby promoting apoptosis **(Mikhailova, 2023)**, as illustrated in Fig. (6).

Antioxidant activity

Both enzymatic and non-enzymatic antioxidants, whether hydrophilic or lipophilic, counteract the oxidative effects of free radicals and other reactive substances. Various nanoparticles, including SeNPs, have been shown to exhibit strong antioxidant activity **(Alhawiti, 2024)**. This effect is not only attributed to the chemical activity and antioxidant potential of the capping biomolecules but also to the small particle size of green-synthesized SeNPs, which enhances dispersion in the medium and improves free radical scavenging efficiency **(Bapte *et al*., 2022)**.

Antidiabetic activity

Diabetes mellitus is a group of endocrine disorders associated with impaired glucose absorption resulting from either absolute or relative insulin deficiency **(Mikhailova, 2023)**. Biogenically synthesized SeNPs (commonly prepared in the presence of bovine serum albumin [BSA] when sodium selenite is reduced with glutathione) have been reported to improve serum insulin levels in diabetic mice. SeNPs also significantly reduced glucose-6-phosphatase activity, total lipids, total cholesterol, triglycerides, and low-density lipoprotein cholesterol, along with markers of renal function (serum urea, creatinine, and uric acid) and hepatic function (serum ALT, AST, and ALP) **(Al-Quraishy *et al*., 2015)**.

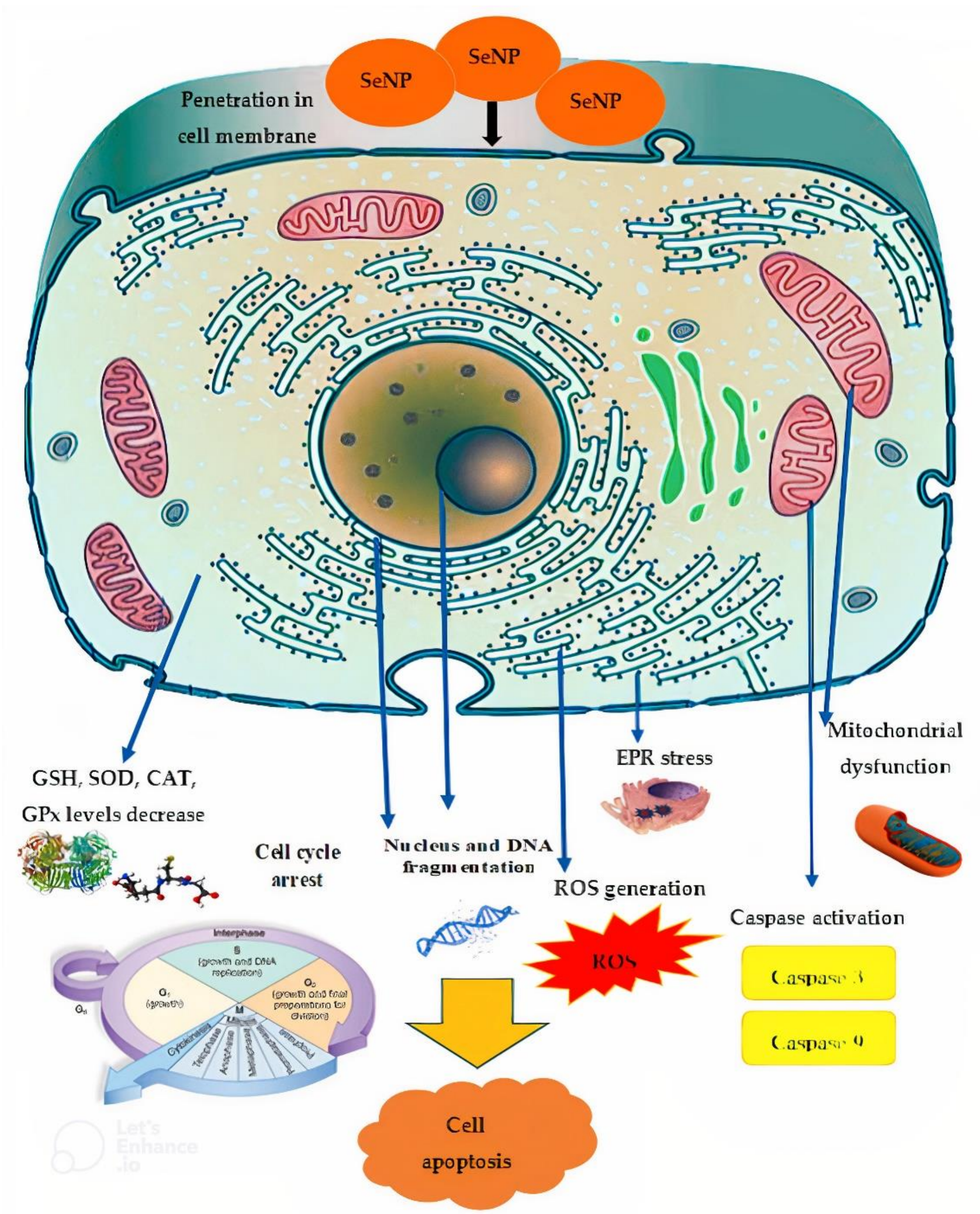

Fig. 6. Mechanism of anticancer activity of selenium nanoparticles (SeNPs) through oxidative stress and apoptosis induction **(Mikhailova, 2023)**

Anti-inflammatory activity

Inflammation is one of the earliest stages in the development of many diseases. Recent studies suggest that selenium nanoparticles (SeNPs) possess anti-inflammatory properties. Cytokines such as TNF-α, IFN-γ, IL-6, and IL-8 play central roles in initiating and regulating inflammatory responses **(Xu *et al*., 2019)**. Green-synthesized SeNPs demonstrated anti-inflammatory efficiency by reducing pro-inflammatory cytokine levels and inhibiting the activity of glial fibrillar acidic protein. This effect was particularly evident against PTZ-induced neuroinflammation, highlighting their potential in suppressing inflammation associated with epilepsy **(Mikhailova, 2023)**.

Antiparasitic activity

Green SeNPs have also demonstrated larvicidal activity. Exposure to SeNPs caused tissue and cellular damage in *Aedes aegypti* and *Culex quinquefasciatus* larvae. Selenium nanoparticles synthesized from *Dillenia indica* leaf extract were shown to exert harmful effects within the cuticle and peripheral cells of mosquito larvae and pupae. In addition, SeNPs mediated by *Cupressus sempervirens* induced pathological changes in the epithelial cells of *Culex pipiens* and were found to penetrate and accumulate in the exoskeleton **(Fadl *et al*., 2022)**.

Agricultural applications of SeNPs

Benefits of selenium for plants

Numerous studies have demonstrated that low concentrations of selenium stimulate plant growth (Fig. 6). For example, the application of 5µg Se increased relative water content by 13% and improved root growth in hot pepper plants compared to controls **(Mozafariyan *et al*., 2014)**. Similarly, Se concentrations of 3– 5µM enhanced leaf area by 25%, leading to increased biomass accumulation.

SeNPs also enhance plant tolerance to heavy metal (HM) stress by upregulating genes responsible for detoxification and antioxidant protection (e.g., SOD, CAT) **(Li *et al*., 2019)**. Furthermore, SeNPs reduce heavy metal bioavailability by binding with them to form stable complexes **(Yuan *et al*., 2024)**, as illustrated in Fig. (7).

Selenium in the soil system

Soils containing more than 4.0mg/ kg Se are considered selenium-rich, whereas soils with less than 0.5mg/ kg are selenium-poor **(Huang *et al*., 2023)**. Selenium concentrations are estimated at ~2×10^{-4} mg/L in ocean water and ~5×10^{-2} mg/kg in the Earth's crust. The chemical species and total selenium concentration determine its bioavailability. In soil, selenium may occur as organic compounds (e.g., selenomethionine), selenide, elemental selenium, selenite, or selenate. Of these, the majority of water-soluble Se forms are readily available to plants.

Several factors influence selenium bioavailability in soils, including clay content, sesquioxides, organic matter (OM), pH, redox potential (Eh), biological activity, and overall selenium concentration **(Stroud *et al*., 2010; Liu *et al*., 2021)**. The selenium ecological cycle is illustrated in Fig. (8).

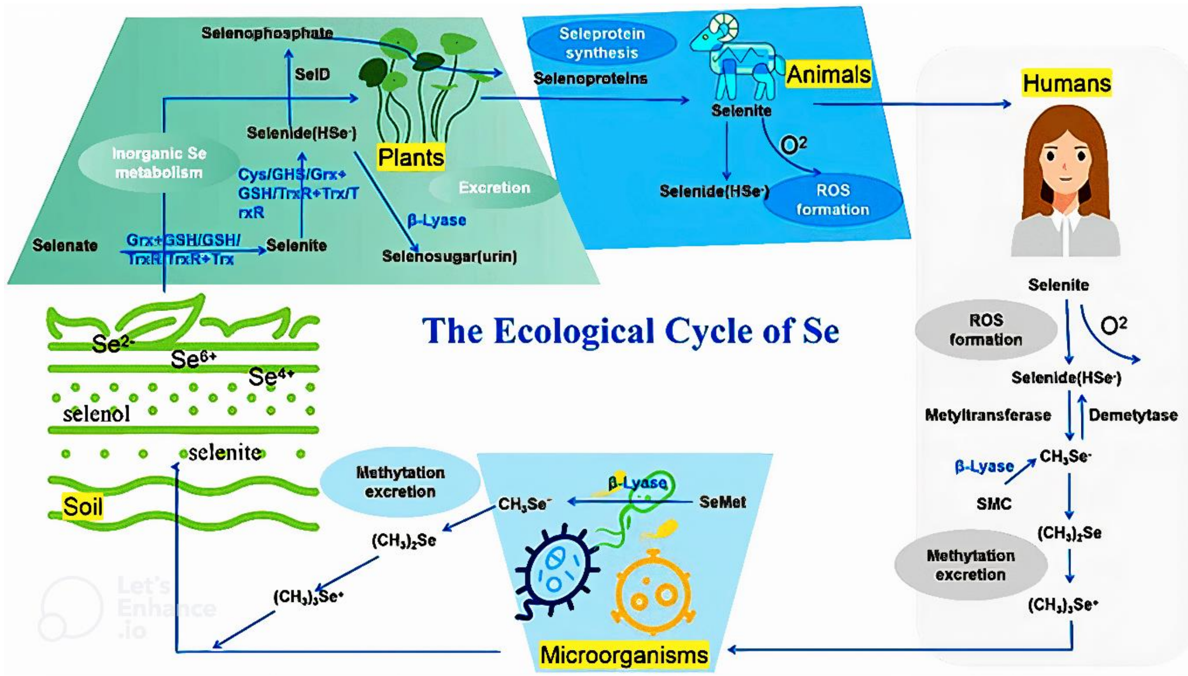

Fig. 7. Schematic representation of the effects of selenium nanoparticles (SeNPs) on plant growth, yield, stress tolerance, and disease resistance **(Tsivileva *et al*., 2025)**

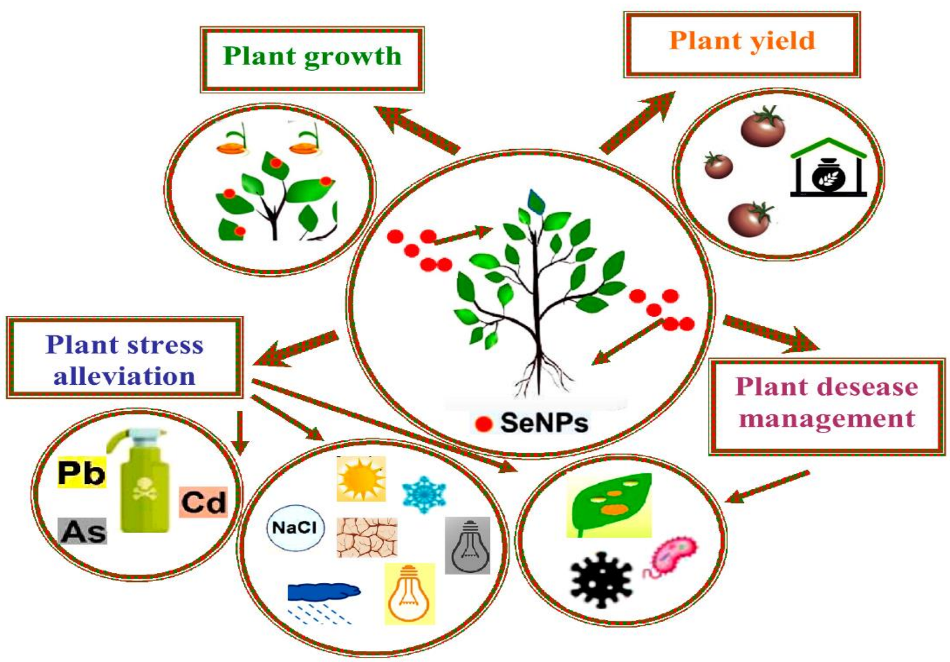

Fig. 8. The ecological cycle of selenium across soil, plants, microorganisms, animals, and humans **(Huang *et al*., 2023)**

9. Adsorption of heavy metals by biogenic elemental selenium nanoparticles

BioSeNPs, or biologically produced elemental selenium nanoparticles, may serve as a novel adsorbent for heavy metal cations such as lead (Pb), cadmium(Cd), copper(Cu), nickel(Ni), and zinc (Zn) **(Buchs *et al.*, 2013; Jain *et al.*, 2014)**.

According to reports, BioSeNPs, or biogenic selenium nanoparticles, have a greater capacity to trap mercury (Hg) **(Wang *et al.*, 2019)**. Furthermore, the following reaction has demonstrated that BioSeNPs is an effective bioremediation technique in order to immobilize elemental mercury (Hg^0) in soil and water: ΔG0 = -38.1 kj mol^{-1} = Hg0 + Se0 → HgSe **(Wang *et al.*, 2017; Wang *et al.*, 2018)**.

CONCLUSION

This review provides a comprehensive and updated overview of the biological mechanisms involved in selenium oxyanion reduction, with particular emphasis on the microbial transformation pathways and genetic diversity of selenite-reducing bacteria (SRB), as characterized through molecular techniques such as ISSR and SDS-PAGE. The biogenesis and allotropic transformation of Se into elemental selenium nanoparticles (SeNPs) offer significant biotechnological potential. SeNPs have demonstrated multifunctional roles, particularly in biomedical applications (e.g., antioxidant, antibacterial, anticancer), as well as in agriculture for enhancing plant growth, stress tolerance, and disease resistance. Moreover, their high adsorption capacity and strong antimicrobial properties suggest their suitability as eco-friendly biofilters for the removal of toxic metals such as Hg^{2+} and nanocontaminants from wastewater. These findings highlight the importance of SeNPs in ecological environmental and biomedical applications and highlight the need for further investigation into their mechanisms of action and field-scale applications.

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الملخص العربي

نظرة عامة على التحول الحيوي لأنواع السيلينيوم بواسطة البكتيريا من أشجار المانغروف ،البحر الأحمر ، مصر وتطبيقاتها

الملخص العربي

السيلينيوم هو عنصر أثري أساسي، وفي تركيزه المنخفض، يكون أساسيا للحياة. ومع ذلك، عند التركيزات الأعلى قليلاً، يصبح الأمر خطيرًا. ينتشر السيلينيوم على نطاق واسع في البيئة، بما في ذلك التربة والمياه والنباتات ومياه الصرف الصحي ومواقع التعدين والغلاف الجوي. لقد حظيت عملية تحويل السيلينيت إلى السيلينيوم العنصري باهتمام كبير بسبب نطاق تطبيقاتها الواسع وخصائصها الاستثنائية وبسبب سمية المواد الكيميائية المستخدمة في الطرق التقليدية. ومن ثم، هناك حاجة إلى التركيب الأخضر، أو البدائل الصديقة للبيئة. من أجل اختزال السيلينيت بشكل فعال إلى عنصر السيلينيوم، يعد عزل وتوصيف السلالات البكتيرية المحبة للملوحة التي تقلل السيلينيت من النظام البيئي الفريد لأشجار المانغروف في البحر الأحمر أمرًا بالغ الأهمية.

يعد فهم التنوع الجيني داخل هذه السلالات أمرًا أساسيًا، حيث يمكن أن يؤثر التنوع الجيني على قدراتها الأيضية وكفاءة تقليل السيلينيت. تتوفر حاليًا العديد من التقنيات الجزيئية، مثل تسلسل الحمض النووي والتحليل البروتيني، مما يوفر أدوات قوية لتقييم التنوع البيولوجي على المستويين الجيني والظاهري. تمكن هذه الأساليب من التعرف الدقيق على الجينات الوظيفية والمسارات المشاركة في التحول الحيوي للسيلينيت.

يركز هذا البحث على كيفية قيام الكائنات الحية الدقيقة بتحويل السيلينيوم غير العضوي إلى أشكال عضوية أقل خطورة. كما يدرس أيضًا التخليق الحيوي والآليات الأساسية لجسيمات السيلينيوم النانوية(BioSeNPs) ، ويسلط الضوء على تطبيقاتها الطبية المتنوعة، بما في ذلك استخداماتها المضادة للبكتيريا والفيروسات والسرطان ومضادات الأكسدة والمضادة للالتهابات والزراعية ومعالجة المعادن الثقيلة. تهدف الدراسة إلى تحديد وتطوير سلالات بكتيرية ذات قدرة متزايدة على تحويل وتجميع السيلينيوم، مما يساهم في نهاية المطاف في إنتاج منتجات أكثر أمانًا وفعالية تعتمد على السيلينيوم.