IJEPEM
Int. J. of Environmental Pollution & Environmental Modelling, Vol. 2(4): 196-211 (2019)
(Review Paper)

Nanotechnology Applications in Agriculture (Review Article)

Essam Hoballah[1], Mohamed Saber[1], Alaa Zaghloul[2*]

[1] Department of Agricultural Microbiology, National Research Centre, Dokki, Cairo, Egypt
[2] Soils and Water Use Department, National Research Centre, Dokki, Cairo, Egypt

E-Mail: *alaazaghloul2008@gmail.com*

Abstract: This state of the art appraises the foremost recent pronouncements in the field of nanotechnology particularly their applications in farming. It covers diverse themes associated with nanotechnology. Nanotechnology was developed and materialized over a lengthy period of time. Actually, various sorts of nanoparticles liable to composition, size, form, and/or structure were described. Different ways and protocols were designed for synthesizing nanoparticles; the most common ones involved chemical, physical, green and/or biological conducts. However, the superiority of biological methods compared to chemical and physical methods was clarified. Additionally, yeasts display an imperative perform in manufacturing nanoparticles that conceived their cells might be the factory producing nanoparticles. The foremost important tools used for characterizing nanoparticles were mentioned in order that they could be employed to estimate their differential futures and characteristics. Fundamentals of some nanoparticle biotechnological synthesis mechanisms were represented in order that they could be exploited to illustrate; optimize and maximize the nanoparticles biosynthesizing process. Several verified nanotechnological structure outputs were applied in farming represented, such as nanobiosensors, nanopesticides, nanocapsules as the sake of the efficient delivery of agrochemicals, plant disease, and weed control agents, nanofertilizers and nanostructures as detoxifying or remediating pollutants, as well as nanotechnological structure material safety aspects.
Kewwords: Nanomaterials, synthesizing, Bio-manufacturing, characterization, mechanisms, safety

INTRODUCTION AND DEFINITIONS

The scope of nanotechnology is associate vastly promoting domain as results of its broad-extending implementation in various regions of science and technology. The expression nanotechnology is described as the designation, utilization, and synthesis of structures at a size less than 1 μm. The term "nano" obtained from a Grecian word dwarf or considerably tiny, once it appears as a mensuration of 10^{-9} m due to International System of Units [1]. The conception of nanotechnology was described by Richard Feynman Prof. of Physics; nevertheless, the expression nanotechnology was represented by Tokyo Science Univ. Prof. Norio Taniguchi [2]. Nanobiotechnology as a participating term, it includes study and development of technology in several domains of science such as chemistry, physics, materials science, technology and biotechnology [3]. The nanoparticles are metal in the form of particles that measure 1–100 nm and display completely various shapes such as rod, spherical, triangular, etc. The studies of the synthesis of nanoparticles are that the present extent of attention because of the distinctive visual properties (physical, optical and chemical) of nanoparticles contrasted with the majority extent material [4].

Before discussing nanotechnological materials and applications, it's necessary to remind that nano-matter definitely occurred in nature before they magnetized the attention of researchers. The carbon nanostructures are constantly generated and emitted within the ambiance by jungle fires and volcanic outburst. From another vision, the lotus plant (*Nymphaea lotus*) is revered for its exceptional cleanness (Lotus-Effect). Though it grows in muddy waters, its leaves perpetually seem immaculately clean, because of, water-repellent, wax aggregates in nano size type three-dimensional structures, almost like tiny nipples that are not any bigger than a few nanometers in size. On another view, the initial attention of nanomaterials, perhaps, returned to the 4th and 8th centuries once discovered the use of nano-objects in technology is that the legendary Damascus steel. Damascus swords were earned for their strength and sharpness. They were notable for being therefore sharp that they might cut a silk scarf into halves because it fell to the bottom, however, European swords couldn't do. They were also renowned for their gracefulness. Their secrets were revealed recently. It seems that a saber fabricated from steel is bolstered by differentiated nanoparticles of carbon nanotubes. Also, nanostructures might be found in muddy

*Corresponding E-mail: *alaazaghloul2008@gmail.com*

water and wastewater sludge ponds formed in agricultural fields, atmospheric emissions, or soil materials that have leached/eroded into those ponds [5].

The observations mentioned by microscopical studies of different elements were carried out a long time ago, process accurate size and measures. The dimensions of structure refer to the interface spacing between the metal atoms of the elemental structure or the longitude of bonds. The longitude of bounds between carbon atoms (C-C) in graphite is 142.6 picometers (10^{-12} m), the longitude of bounds between nickel atoms (Ni–Ni) is 249.2 picometers, and however, nitrogen has an atomic radius of 65 picometers, Oxygen 60 picometers and Carbon 70 picometers. The dimension of balanced atoms objected on the method during measurement operation. Novel innovations and directions in structural science derived for synthesizing of many transference metals of nanoparticles dimension. Nanoparticles synthesis methods are chiefly classified into 4 main groups: physical, chemical, green, and biological techniques. Progress within the nanotechnology term has been speedy by the event of novel synthesis developing and characterizing techniques [6]. However, foremost of synthesizing techniques are restricted synthesizing of nanostructures in tiny sizes and weak morphology. Nanotechnological forming includes the nanoparticles synthesis employing the destruction theory process (top-down) or the building theory process (bottom-up) approach [6]. The chemically and physically technique synthesizing processes are predominantly performed synthesizing of different weak morphology structures, however these techniques demonstrated to the environmental virulently because of virulent chemicals and conjointly of raised temperature degrees and pressure conditions for synthesizing processes [7].

The biological synthesis of nanoparticles controlled morphology requests a lot of interest, when the nanoparticles biological synthesis is achieved by employing of microbiological suggests such as different bacteria, fungi, actinomycetes and algae. The microorganisms have the ability for excreting great value of biochemical molecules that are responsible for synthesizing nanoparticles by reduction and morphology management of metal ions. The microorganisms culturing are simple to be applied, thus the conjoint process of obtaining microbial biomass is uncomplicated as contrasted to the synthetic techniques [8].

Nanostructures of some metals provide different applications in several arrays through agricultural farming like catalyzing agents, and biotechnological sensors. Nanoparticles distinctive characteristics could permit their employing within pesticides revealing and destruction in water and soil. Many researchers represented the rising current of patents and scientific broadcasting together in the agricultural farming nanotechnological applications particularly for crop preservation and phytopathogenic management. Nanostructures in agricultural farming especially aiming to minimize the quantities of utilized chemical inclusions by minimizing refining transmission of active constituents; minimize nutrient wastage in fertilization and raising the yields via optimizing the nutrient management and water utilization. From another view, nanotechnology is one among the quickest growing technological fields of the twenty-first century; however, the success of the rising nanotechnology applications can rely upon the dynamic development of nanomaterial toxicology, risk, and exposure assessment [9].

Nanomaterial structures

Nanostructures illustrated that an innate, transverse or produced nanostructural containing particles in ultimate form, in aggregate form or in agglomerated form and wherever, for fifty percent or additional of the nanostructure particles within the range dimension of 1-100 nm. From nanotechnological point of view, the particle, aggregate and agglomerate forms explained as the following: (a) Particle form indicates that tiny bit of matter within outlined physically skeleton; (b) Agglomerate form indicates that gathering of decrepit certain particles and/ or aggregates wherever the ensuing the area of external surface is analogous to the summation of the single component surface areas; (c) Aggregate form indicates that a constitution of particles powerfully conjugated or healed nanostructured particles [9].

Main types of nanomaterials (Nanostructured materials) matching the EU [5] definitions

Various nanostructures are corresponded by both of European Commission and International Organization for Standardization, for nanostructural material qualifications. Initially, these are the nanomaterials structure that includes nanostructural objects or includes a serious portion therefrom.

Nanosuspensions structure material

The nanosuspensions composition comprises of pended or spread nanostructured solids in a liquid state. A typical expression to explain an analogous category of nanosuspension is that structural colloid.

Nanoaerosols structure material

The nanoaerosols are nanostructures that include a gas state comprising free mobile nanoobjects. It's not simple to provide nanoaerosols structures that have enough of steadiness to permit commercial transport.

Nanoemulsions structure material

The nanoemulsions structure comprises of liquid nanostructure pended or spread in a liquid state.

Nanoparticles structure material

The nanoparticle structures are particles with a minimum of one morphological proportion at the nanolader. Enormous increasing comprised to the range of particles is designed to possess its inner nanolader options. A number of these structures present an exterior diameter less than 100 nm, corresponding to the European Commission International Organization nanostructures qualifications; among others comprise an exterior diameter more than 100 nm, not corresponding to the European Commission International Organization nanomaterial qualification. Additionally, the last qualified nanomaterials supported the nanolader size of their cover supported the nanolader size of the core structure.

Nanocomposite structure materials

The nanocomposite structures are complex mixture varied styles of nano- and non-nanostructures. Nanocomposite structures (or nanocomposites) included at least 2 different phases, a minimum of one among that has nanoscale options.

Dendrimers structure material

Dendrimers are tree-shaped molecular structures kind of like polymers.

Quantum dots

The quantum dots nanostructures are semiconductors have electronic futures that widely associated with the measure and form of the single crystal structure. Regular quantum dots are composed of nanostructural materials such as Cd Se, Cd S and In P.

Nanoporous materials and nanofoams

- Nanoporous structure materials

The nanoporous structures are structural materials composing a part of tiny pores, in nanoscale measurements. The appointed future of nanoporous material is that the measure of the nanopore structure. Thus, nanoporous materials are not lined corresponding to the nanomaterial qualification like zeolite clay mineral.

- Liquid structure nanofoams

Liquid structure nanofoam comprises of gas bubbles in nanoscale measurement enclosed by the specific liquid state.

Classification of nanoparticles

Nanoparticle structural materials are generally distributed into three types:

-One-dimensional nanoparticle structures. (Attenuate film or designed surface).
-Two-dimensional nanoparticle structures such as carbon nanotube structures.
-Three-dimensional nanoparticle structures such as fullerenes, quantum dots, and dendrimers.

Nanoparticles synthesizing by different ways and methods

An important part of the foremost necessary portion in studding nanotechnology is that responsible for the synthesizing future of scale, morphology and controlled monostructure of metal nanostructures. The foremost simple technique for preparing that nanostructure is supported caustic chemicals, such as vigorously reducers, surfactant materials, polymers enveloping agent and, often, many of organic solvents, to realize powerful outcomes. Thus, many necessary requirements are demanded to evolve nanoparticle synthesizing processes is friendly to the environment that don't employ harsh chemical materials in their synthesizing techniques. Therefore, many research authors within the term of nanoparticle structure synthesis converted their synthesizing protocols into microbiological ways for renovation. Several microorganisms are identified to manufacture inorganic nanomaterial structures (either internal or external) with attributes like nanomaterials that synthesized by chemical techniques. The synthesis of nanomaterial structures like silicon oxide, metal and metal alloy nanostructures by biomolecules is recognized as biological mineralization process. It is worthy of the attention that, employing the applied ambient conditions in all of the biomineralization processes or nanoparticles biological synthesized products. Therefore, in several statuses, the nanomaterial structures are made below genetical management leading to particular morphologies, crystallinity and size, of the nanostructures [4].

Because of the wide selection of nanostructural particle applications in numerous ways of the scientific-technological aspects, totally various techniques are intended for their manufacture. The nanoparticle structures could be manufactured employing the destruction theory process (top-down) as physical discipline that transact with the techniques liked- arc discharge (in a gas or vapor it is an electrical current run out between electrodes, that have high current density) diffusion, irradiation and thermal decomposition, and the building theory process (bottom up) approach that included in chemical and biological protocols which includes growth building technique, polyol forming technique, electrochemical manufacturing technique, chemical reduction technique, and microbiological technique for manufacturing nanoparticle structures. Totally various manufacturing protocols included the use of various chemical styles, physical styles, green styles and microbiological ways to produce nanoparticle structures of various scales and forms [10].

Chemical methods

Foremost typically used technique for the chemical manufacturing of nanoparticle structures is that the chemical reduction process technique, that transacts with the reduction process of elemental matter to nanoparticle structure employing chemical reducers such as $NaBH_4$ (sodium borohydride) or $Na_3C_6H_5O_7$ (sodium citrate). Bottom-up (the growth building theory process) technique is a colloidal technique in chemistry for the manufacturing of nanoparticle structures that included bottom-up brick by the reducing of metal ions found with the acceptable chemical inclusions [9].

Physical methods

The physical ways employed for the manufacturing of nanoparticle structures involve thermal decomposition, diffusion, electrolysis condensation and laser irradiation. The thermal decomposition technique is employed for the manufacturing of monostructure of nanoparticles [9].

Green (plant extracts) methods

Green (plant extracts) synthesis of nanoparticles includes the employment of different plant inclusions or biological molecules for the manufacturing of nanoparticle structures. The green synthesis methods employ comparatively nonpoisonous chemicals to manufacture nanomaterial structures and involve the employment of nonpoisonous solvents like biotechnological extracts and water. The scale of nanoparticle structures (analogous <30 nm) based on their integration properties like surface acidity, oxidation, electron transference, decomposition, oxidoreduction cycles, adsorption & desorption and surface acido-basicity degeneration. The green manufacture of nanoparticles has been encountered as nanoparticles growing technique. Various plant biomolecules play an important role as bioreducers that convert the metal ions into nanoparticle structures, leading to the manufacturing of nanoparticle structures. The biomolecules and organic compound in the plant extracts employed therefore within the manufacturing of nanoparticle structures that they play a role in reducing factor and also as covering factor. Many plant extracts like *Phyllanthus amla*, geranium, coriander, *Aloe vera* and neem tea tree leaves, Alfalfa and *Capsicum annum* were employed for green manufacturing. Plant reducing factors are concerned within the reduction of the metal process involved varied colloidal simple product in water (e.g., alkaloids, phenolic compounds, terpenoids, flavonoids, and coenzymes). Many research authors targeted basically on the manufacture of Ag^0 (silver) and Au^0 (gold) nanoparticle structures for the importance of their medical and environmental applications [11].

Biological methods

The microorganisms employed in manufacturing various nanoparticle structures involved mostly microorganisms and plants. The biological techniques employed to synthesize nanoparticle structures involved both exterior and interior techniques [5].

Superiority of biological nanoparticles synthesizing methods compared to chemical and physical methods

The physical and chemical techniques

Different styles of nanotechnological physical and chemical techniques are utilized for manufacturing of nanoparticle structures. The utilization of those manufacture techniques needs both powerful and powerless chemical reducing factors, protecting factors that are principal, could be not simply regulated of owing to the environmental problems, poisonous and flammable and additionally explain a weak manufacturing rate. Additionally, in several statuses, manufacture is administered at cumulative temperature degrees, that consume a large quantity of overheat. A pattern, on the technique of the synthesizing process and thermal decomposition, is administered at a terribly extreme overheat [9].

The biological techniques

The biotechnological technique for manufacturing of nanoparticle structures employs various microbiological techniques like bacteria, fungi, actinomycetes, yeast, algae, and plant extracts. Therefore, the microbiological technique provides a good variety of different resources for manufacturing of nanoparticle structures. The metal ions rate of reduction employing the microbiological entities found to be a lot of quicker and at ambient different conditions such as temperature and pressure degrees. As an example, just in the status of manufacture of nanoparticle structures employing fungi like *Aspergillus niger*, for synthesizing silver nanoparticle structures was monitored within 2 hours of fungal filtrates treatment with the silver salt dilution. Therefore, the biological technique requires minimum time and environmentally safe chemicals of the microbiological media for manufacturing of nanoparticle structures [8].

Some different microbiological agents employed for the manufacture of nanoparticle structures

Bacteria mediated manufacture of nanomaterial structures

The manufacturing of nanoparticle structures employing many microbiological individuals such as bacteria and actinomycetes that commonly comprises the intracellular manufacturing technique. Whether, the bacterial cell pellet obtained from centrifugation is patronized with a metal salt dilution and incubated in dark at ambient conditions (temperature and pressure). Extracellular manufacturing technique of nanoparticle structures employing bacteria cells precipitated from their liquid culture by centrifugation at 8,000 g and then the supernatant is resumed with the used metal salt solution [5].

Fungi mediated manufacture of nanomaterial structures

The biological extracellular manufacture of nanomaterial structures included eukaryotic individuals like fungi that exhibit many benefits. Which is often primarily as a result of fungi: (a) could be grow under controlled environmental conditions with proportional ease (b) fungi are most tolerance to different mutations than bacteria and will thus maintain nanoparticle structure manufacture ability for prolonged inhabitance, and (c) fungi are recognized to supply luxuriant values of external enzymes and proteins that are responsible for the processing and converting of the elemental ions to nanoparticle structures [12]. These characteristics pay fungi thallus to be the biological commercial biofermentation techniques for manufacturing nanoparticle structures. Just in case of fungi, nanoparticle structures are intracellularly manufactured by patronizing the fungal thallus with the metal salt dilutions under shaking incubation for 24 hours. The dried fungal mycelium is additionally employed for synthesizing of nanoparticles. During this technique, the mycelium of fungi is harvested and later on lifolized, and then it is treated with the metal salt dilution thereafter incubated for 24 hours. Though, within the extracellular technique, the pellet of the centrifuged fungal culture is deal with a metal salt solution and then incubated for 24 hours [13].

Algae Mediated manufacture of nanomaterial structures

The algal manufacturing of nanoparticle structures technique, the algal washed cells separated from growing medium and then treated with metal salt dilutions and incubated in dark with monitored pH and temperature conditions. The cell-free liquid culture containing nanoparticles is crammed within the flask to the edge and then left at -20ºC in standing direction. Throughout freezing, the nanoparticle structures attain thicker than the initial medium and move down [8].

Size management over the biological synthesis of the nanoparticles

The controlled morphology and nanoscale of nanoparticle structures might be manufactured by altering the pH or the temperature degrees of the synthesizing mixture. Gericke and Pinches [14] attained totally different morphological forms (rods, spheres, triangle and hexagons) by altering the pH degree of the synthesizing mixture. Riddin et al. [15] observed that at a 65ºC temperature degree, a few silver nanoparticle structures was manufactured, while at 35ºC temperature degree additional quantity of nanoparticle structures was manufactured. At ambient (about 25ºC) temperature condition, silver nanoparticle structures of 50 nm scale are manufactured while at 60ºC degree nanoparticles of 15 nm scale are manufactured. Analogous, at acidic pH condition the nanoscale of the nanoparticles structures ranged 45 nm, while at pH 10 the scale could be 15 nm. So that, the silver nanoparticle structures scale of 2–20 nm could be manufactured by fungal thallus of *Verticillium* sp. The fungal thallus secretes an oversized quantity of reduction enzymes that are able to reduce metals ions and therefore creating nanoparticle structures [16]. Just in case of fungi, the nitrate reductase enzyme is constructed to be liable for the manufacturing of nanoparticle structures [9,17].

Microbial ability screening for synthesizing of nanoparticles

Novel alternative methods to chemical and physical techniques raised when biosynthetic techniques using either microorganism or plant extracts have recognized a straightforward. The biological output of nanoparticle structures employing microorganisms could be outlined as a new style of the bottom-up method that the atoms are built to grow consecutively from tiny to larger particle structural scale [4]. In fact, biological manufacturing is more important for the commercial admission when the nanoparticle structures might be manufactured faster and economically in large values [18].

Microbiological screening for nanoparticle structures synthesizing ability is one of the foremost serious states for discovering a microorganism that could manufacture particular metal nanoparticle structure. On the screening ability technique, microorganism's genera like the native type culture collections are often screened. The transformation of some metal ions to their nanostructural metallic forms will happen by a technique of microorganisms separated from various metal enriched environments like wastewater, lakes water, seawater and metal-involving waste product from some industrial waste water. An assortment of specimens from these locations could be a high advantage for attaining a microorganism is active to manufacture particular metal ions into nanoparticle structures. Attaining and enrichment of microorganisms able to produce nanoparticles ought to be distributed by employing culture media accomplished with the required elemental ions at various concentrations. With a view to determining which microorganism colony might manufacture the elemental nanoparticle structures, a recognizable sign like alteration in cultivation media color because of nanoparticle structure output [7].

An example of a technical procedure for microbial ability screening to synthesize nanoparticles

An example of a technical procedure in laboratory scale, the screening ability of selenium nanoparticle structure manufacturer and regarded strategies for biological nanoparticle structure synthesizing are corresponded (Figure 1) [19].

- Sampling ought to be followed by gathering water specimens from varied sites like waste water, rivers, seawater or lakes wherever the metal ions dens is could be rise.
- Thereafter, continued by serial dilution step employing saline settling solution in a tenfold dilution from the primary bottle.
- Isolation is that the following step exploiting agar medium with completely different concentrations of filtration sterilized selenium salt (such as SeO_2 or $SeCl_4$) and poured on tiny a part of water sample in check plates and incubates at suitable temperature degree for 24–48 hours. The observation of reddish color colonies could be a proof of selenium nanoparticle structures manufacturer microorganism.
- To confirm that the reddish color isn't contributive to alternative microorganism pigments, transmit these colonies onto the prepared agar plates out of selenium ions.
- Pure culture ought to be obtained from the microorganism mass isolated at the primary screening for identification, characterization, and further studies.

Why microorganisms synthesize nanoparticles?

Living cells offer distinctive conditions for increase extremely regulated, nanoscale structures, including restructuring materials, catalysis, and controlled biosynthesizing process. So as to qualify various ecological habitats, microorganisms have assumed specific cell functions. The three major logics for microorganisms to supply nanoparticle structures are: (1) chemolithotrophy for living power output, (2) employing of those particle structures for the specific biological mission (as a coenzyme) and (3) detoxification for maintaining survival in poisonous habitat. All of those are recognized mechanisms that are introduced biological manufacturing of nanomaterial structures by microorganisms. Consequently, biotechnological processes like bioleaching and bioremediation are recognized since ancient times to take priority of the capability of microorganisms to gather metals [14].

Why yeasts are considered the cell factory for producing nanoparticles?

To design a biotechnological process chain with industrial significance many vital parameters need careful thought. These embrace precise choice of appropriate strains with distinctive and desired properties, the introduction of cheap various substrates, process opportunity and yield improvement, product characteristics and application necessities. The selection of yeast strains is of major significance for nanoparticles synthesis, specifically concerning their properties. Of all the eukaryotes, yeast species are the foremost studied and applied in bioprocesses that qualify them as a pretty object for nanoparticle synthesis [20].

The external biosynthesizing of nanomaterial structures including microorganisms like yeast and fungi rise more edges to various microorganisms, beside the outputs related to industrial inclusions. Principally yeast and fungi offers high competence for nanoparticles synthesis ability because: (a) could be grown under controlled environmental conditions with proportional ease (b) yeast are most tolerance to different mutations than bacteria and will thus maintain nanoparticle structure manufacture ability for prolonged inhabitance, and (c) yeast are recognized to supply luxuriant values of external enzymes and proteins that are responsible for the processing and converting of the elemental ions to nanoparticle structures [20]. These characteristics pay yeast to be the biological commercial biofermentation techniques manufacturer for synthesizing nanoparticle structures [21].

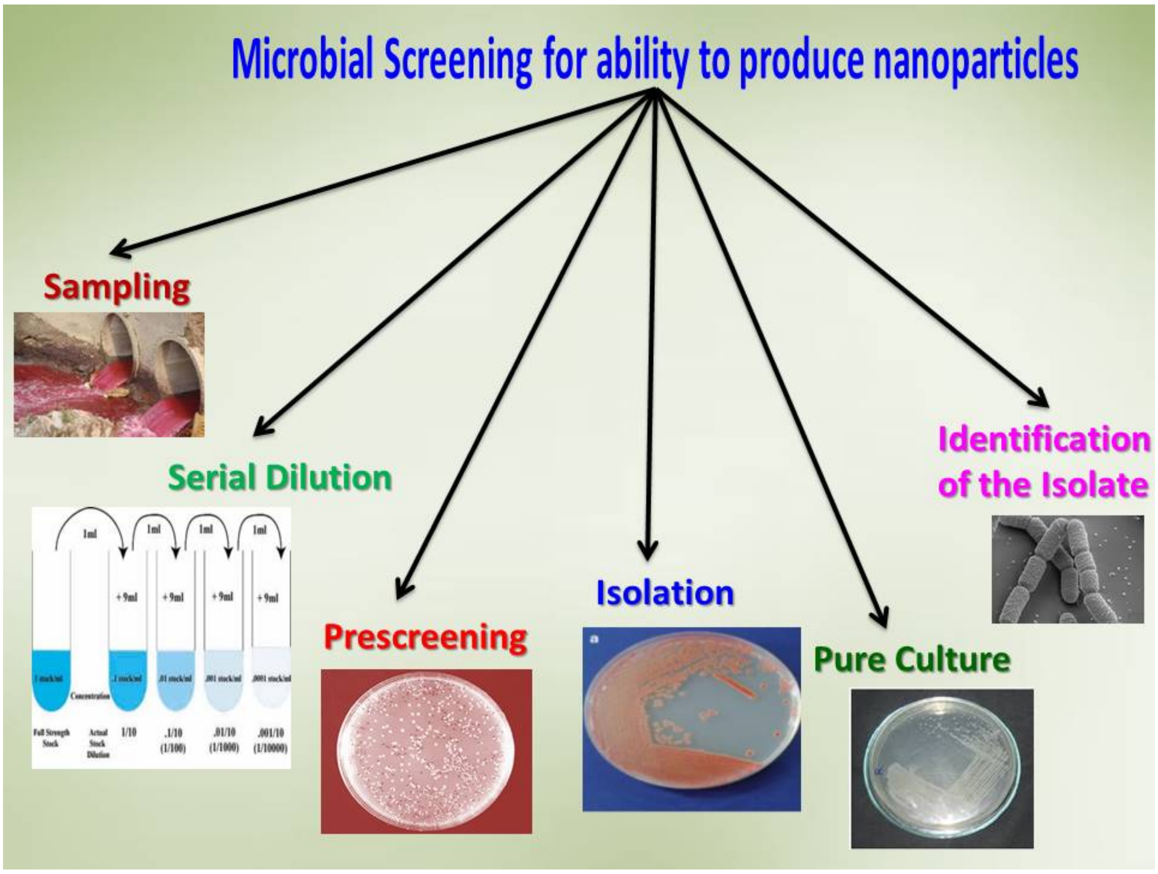

Figure 1 The screening of bacterial ability for synthesizing selenium nanoparticles

Tools employed for studding and characterizing nanomaterials

The characterization of tiny structures or small-sized materials within the nanometric-scale usually refined characterization tools. Characterization of nanomaterials and nanostructures has been mostly supported bound on the certain critical advancement of conventional characterization ways developed for bulk materials. As an example, X-ray diffraction (XRD) has been widely used for the determination of crystalline character, crystal size, crystal structures and lattice constants of nanoparticles, nanowires and thin films. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM), together with electron diffraction, are usually utilized in the characterization of nanoparticles to urge a thought of the size, shape, and defects present in these materials. Scanning probe microscopy (SPM) is new comparatively description protocol and has found widespread application in nanotechnological studies. The two branches of SPM area unit scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The obtained nanoparticles conjointly ought to be described so as to validate their physicochemical characteristics employing a different protocols involving: UV VIS spectroscopy; dynamic light scattering (DLS); zeta potential measurement (Zeta potential is a scientific term for electrokinetic potential or it is the potential difference between the dispersion medium and the stationary layer of fluid attached to the dispersed particle); Fourier Transform Infrared spectroscopy (FTIR); X ray photoelectron spectroscopy (XPS) [1].

Expected mechanisms of nanoparticles biotechnological synthesis

Over various long time of developmental expansion, biotal technology has evolved numerous mechanisms to provide the nanomaterial structures for a vast diversity of objectives. The manufacture of the many alternative metal and metal alloy nanoparticle structures employing microorganisms might be a conclusion of detoxification or remediation processes. The mechanisms involved enzymatic activities for detoxification by reduction of the metal ions to less poisonous metal salts or converting them to zero-valent metals. Several types of research have emphasized that the catalysis activities of reduction enzymes are the most significant mechanisms concerned in bioreduction processes. Various microorganisms, many reducer enzymes are contributing within the bioreduction process including the transfer of electrons from specific electron donors to elemental electron acceptors. The last mentioned mechanisms could be found in the interior or exterior cell complexation and also responsible for forming of metal nanoparticle structures. The perfect mechanisms for the manufacturing of nanoparticle structures employing many biological factors react otherwise with elemental ions and additionally, various biomolecules accountable for the synthesizing processes of nanoparticle structures. The microbial cell wall plays a serious part in the intracellular manufacture of nanoparticle structures. Cell wall has a negative charge that reacts electrostatically with the positively charged elemental ions. Enzymes found in the cell wall could reduce the elemental ions into nanoparticle structures, and eventually, the tiny scale nanoparticle structures could disperse through the cell wall [22].

Extracellular synthesis of nanoparticles using NADH-dependent enzymes

Many mechanisms of microbial extracellular manufacture of nanoparticle structures are essentially found to be nitrate reductase activities manufacturing processes. When the commercially offered nitrate enzyme disks were used to ensure nitrate reductase role in metal nanoparticles synthesis; the color of the disk converted to be reddish from white once objected with microbial cells (filtrate) indicating the presence of nitrate reductase enzyme activity. Thus, it could be involved that the nitrate or sulfate-NADH-dependent reductase is responsible for converting of Ag^+ to Ag^0 by reduction process (Figure 2) within different microorganisms [23]. Also, an identical mechanism was conjointly within the case of extracellular manufacturing of gold nanoparticle structures using *Rhodopseudomonas capsulata* bacterium. R. *capsulata* is recognized to secrete NADH cofactor and NADH-dependent enzymes. The bioreduction of gold ions was pointed to begin by the transference of electron from the NADH by NADH-dependent reductase as an electron carrier [24].

Major intracellular biological molecules contributes in nanoparticles biotechnological synthesis process

Microorganisms are considered prospective bioremediation agents, those gathering elements from their habitats employing actively or passively mechanisms. Various researchers have discovered that most of the yeast genera could accumulate varied toxic metals however significantly attention-grabbing is that the ability to accumulate considerable values of extremely heavy metals [24].

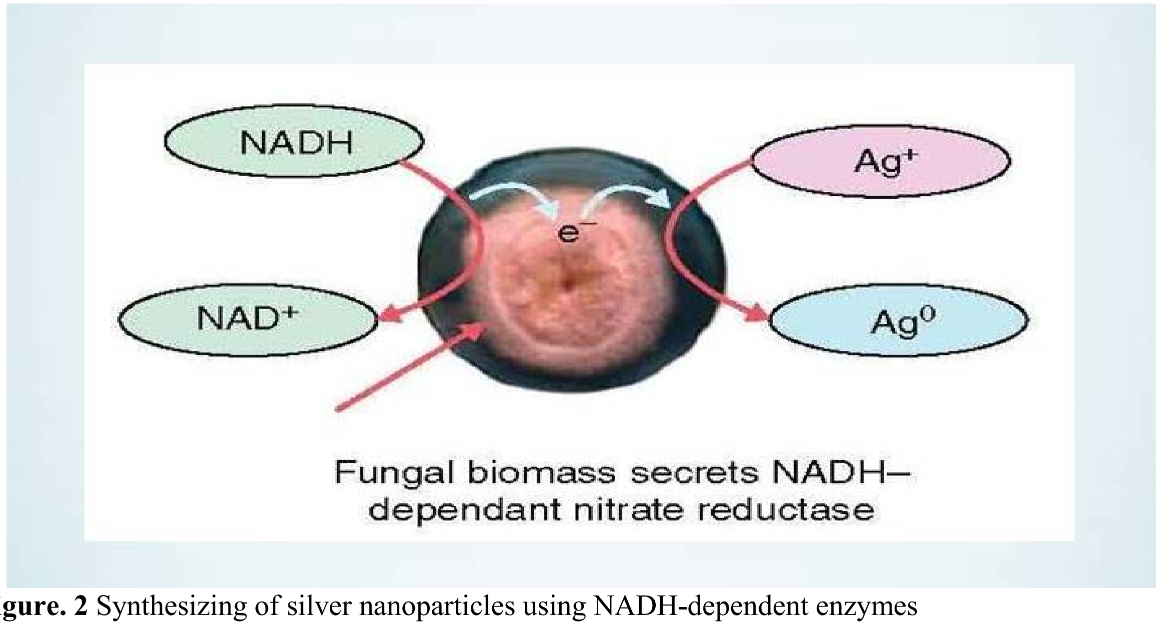

Figure. 2 Synthesizing of silver nanoparticles using NADH-dependent enzymes

Glutathione (GSH) biomolecules

GSH (Glutathione sulfhydryl) accounted a major molecule participate in the detoxification or bioremediation mechanisms in in various microbial cells, GSH (glutamine-Cysteine-Glycine) and other 2 series of metal binding ligands that are metallothioneins and phytochelatins (PC), both of them are recognized (Figure 3). These metal binding molecules confirm the mechanisms of nanoparticle structures formation by many microbial genera by complexed biomolecules (Glutathione reduces disulfide bonds serving as an electron donor). Though lastly they were characterized as metal binding peptides , formation of phytochelatin is induced by wide range of metals like Cd^{2+}, Pb^{2+}, Zn^{2+}, Ag^{+}, Ni^{2+}, Hg^{2+}, Cu^{2+}, Sn^{2+}, SeO_3^{2-}, Au^{+}, once supplemented to the medium [24].

Phytochelatins

Phytochelatins have the general structure that consisted of oligomers of glutathione (Glutathione GSH that consisted of glutamine-Cysteine-Glycine). Phytochelatins are regarding Glutathione GSH, contributing as an for nanoparticles manufacture [24].

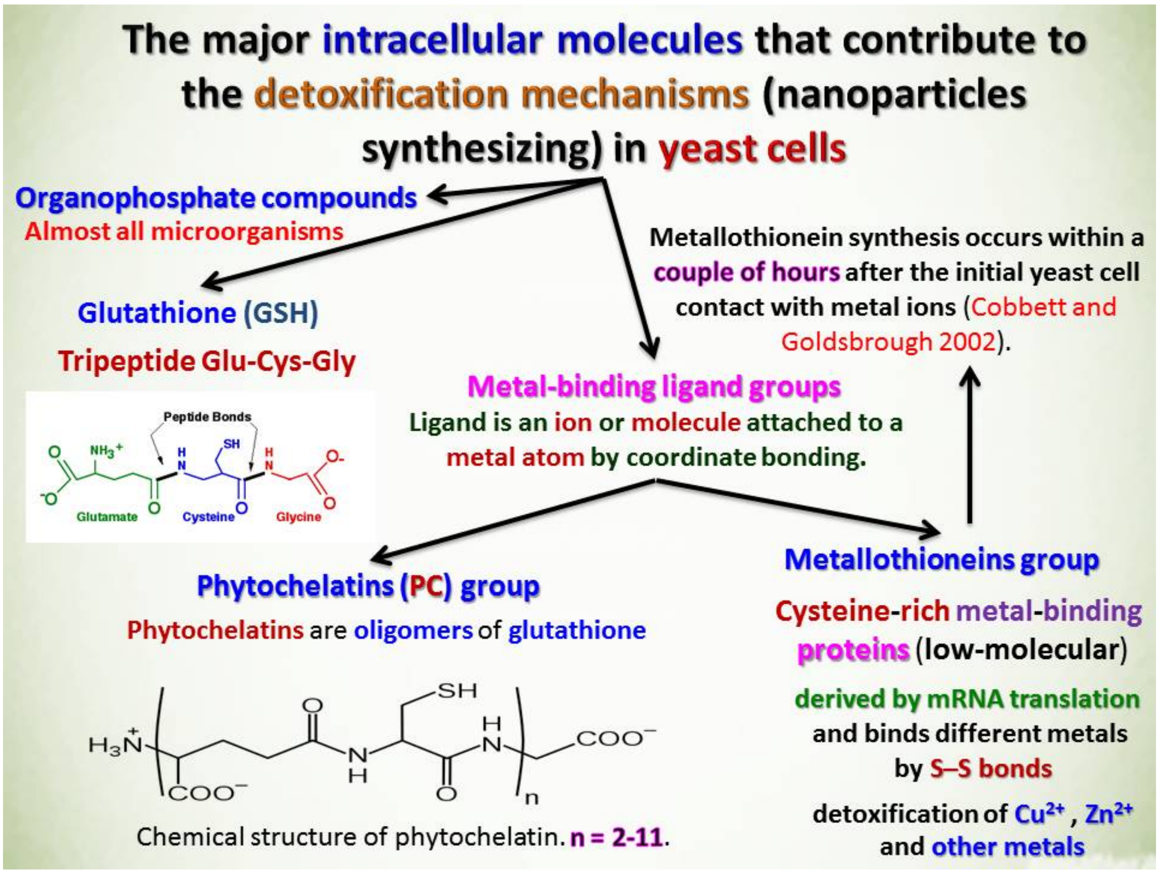

Figure 3 Major intracellular biological molecules contributes in nanoparticles biotechnological synthesis process

Metallothioneins

Metallothioneins are cysteine-rich metal binding proteins. The high value of cysteine connects completely various metals by S–S bonds. Metallothioneins are classified due to the arrangement of those residues to low molecular mass, ability to bind metal ions and specific organic compound composition with high levels of cysteine and low level of aromatic amino acids residues that are common among all metallothionein categories. Metallothionein synthesis appears during two hours once the initial microbial cell connects to the metal ions [24].

Nanotechnological structure applications and potential benefits in agricultural farming

In developing countries the agriculture is considered the backbone. The promising developments regarding the agricultural strip, the powerfully required attributable continuous innovation should be recognized for providing global food security objectives. Within last times, agricultural sector improved by various alternative biotechnological innovations, as well as, biotechnology, synthetic fertilizers and chemicals, and hybrid varieties, Now many authors currently are investigating in nanotechnological aspects as replacement supply of farming enhancements [26].

Nanotechnology is a modern portion in the scientific technological aspects that include the employment of materials and instruments qualified for involving the chemical and physical advantages of a material at molecular scales. Nanotechnology has the possibility to develop and enhance the agricultural sector with modern tools for the molecular management of diseases, rapid detection of diseases, enhancing the power of plants to uptake nutrients, among others. On another point of view, nanobiotechnology will evolve our recognition of the biotechnology used in different crops farming and therefore will doubtless rise farming yields or decrease plant nutritional values, also the farming development required systems for observing environmental futures and improving the capability of plant nutrient uptake or absorb pesticides. Authors have established that the applying of nanotechnological structures is settled to diminish of afflation (fungal toxins) in agriculture that leads to reducing the burden of animals feed toxicity. Also, nanostructured materials catalysts could improve the potency of pesticides and herbicides, permitting little doses to be consumed. Biosensors and fast technological checking associated with the management of insects and objective contamination in agriculture and food production could be led to more applications of nanotechnological structures [5].

Nanobiotechnology and Biosensors

Sensors are refined instruments that replay physicochemical and biotechnological portions that response into a sign or output that might be employed by living objects. A biosensor is a testing tool that includes biological state (like immune and active constituents, nucleic acids, enzymes, cell receptors, Organelles, microbiological cells and tissues) that is in prompt connection with a physicochemical constituent. Nanobiosensor is a testing tool that includes organic or biological state and specific nanoparticle structure of the metal. They permit the disclosure of various contaminants like microbes, nutrient content and plant stress due to drought, temperature, pests, insect or pathogenic stress, or deficiency of nutrients [1].

Qu et al. [27] explained a composite biosensor that consisting of organic polymer and specific nanoparticle metal. The composite expedited the deposition of various polymers involving proteins. E. *coli* detection was improved by the detection scale of 10 CFU/mL employing a new biosensor (tyrosinase) to detect phenol, by using Fe_3O_4 magnetic nanoparticles coated with carbon nanotubes (CNTs). The determination basis has supported the determination of phenol created by the enzymatic reaction within the bacteria that containing the biosensor [5].

Nanoparticles potential benefits for detecting and destructing of pesticides

Synthetic pesticides are unsafe to both creatures and the environment, seriously the pollution of drinking and surface water that reach to various organisms. The distinctive characteristics of nanoparticle structures permit their use within the revealing and degradation of pesticides. The wide volume to surface area proportion features of nanoparticle structures plays an important role in catalyzing employed to degrade pesticides. The destruction of pesticides is known as a photocatalytic oxidation technique that employs titanium dioxide TiO_2 nanoparticle structures in that process. Under enhancement the photocatalysis process is also involved eliminating pesticides and herbicides on plants and also the soil through. Carbamate and dichloropyrifos pesticides utilized in different farming crops are fully destructed within the presence of ZnO and TiO_2 [28].

Nanoparticle structures might be employed in ideal product compositions such as insecticides, pesticides (Insecticides are a type of pesticide that is used to specifically target and kill insects) and insect repellants. Consistent with oil in water (nanoemulsion formulations) was helpful in pesticides nanoemulsion formulations that might be powerful against various insect pests in farming. Typically, volatile oil emulsified as solid lipid Nano-formulations were used as nanoemulsion pesticides [5].

Nanocapsules for efficient delivery of agrochemicals

Nanoencapsulation could be a method through those chemicals like pesticides are slowly however with efficiency released as insect pest control to an appointed host plant. Nanoencapsulation with nanoparticle structures or nanoemulsions in pesticides formulations permits for controlled release and appropriate intake of the chemical formulations into the plants. The release mechanisms of nanoencapsulation involve spreading, degradation, bio-destruction and osmotic pressure under particular pH degree [29].

Nanoparticles and plant disease control

Various nanoparticle structures pervade the stage of controlling plant diseases like aluminum silicates, carbon nanoforms, silicon dioxide and silver. On the same view, nanotechnology has amazed scientific community as a result of nanoscale materials that shows various properties. Whenever, silver represents totally various styles of anti-phytopathogenic agent have become more generic as technological advances tool, paying their outputs more economical products [30]. The anti-fungal potency of the silver nanoparticles colloidal structure are involved as a treatment against fungal plant pathogens; the foremost important potency against plant pathogenic fungi was noted in vitro using 100 ppm of Ag^0 nanoparticles [31]. Also, zinc oxide (ZnO) and magnesium oxide (MgO) nanoparticle structures showed potent antibacterial and anti-odor agents [32].

Nanotechnological structure potential benefits as herbicides

The weed elimination easiest way is the destruction of their seed banks within the soil and stopping their germination once the surrounded conditions is appropriate for growth. Nanocapsules will facilitate the effective invasion of herbicide formulations through plant tissues, permitting slow releasing and organized releasing of the active materials. Nanoporous silica particle nanostructures are formed act as container structure for several chemical compounds into the plants; they induce the plant to occupy the particle structures through the cell walls, with low or without toxic side effects [5].

Nanofertilizers and nanostructure delivery systems for plant hormones

Nano technocrats are qualified for finding out plant's hormone regulations like auxin, cytokinins that are responsible for root growth and seedling organization and affect the internodal length and leaf growth. Nanosensor structures that bind with auxin are developed to be applied in farming. Fertilizers play a polar role in farming production (about 50%). To improve nutrient utilize potency and defeat the severe drawback of plant nutrition, nanofertilizer could be the best alternative. Nanofertilizer structures are manufactured so as to control the nutrients releasing counting on the crops requirements, and it's additionally stated that nanofertilizers are effective than conventional fertilizers. Nanofertilizers might be accustomed to reducing the loss of nitrogen due to volatilization, leaching, and reduction and consumption by soil microorganisms. They might permit controlled release related to time or environment. Regulated controlled release fertilizer could enhance soil by lowering toxic effects related to fertilizer overdose application [37].

Nanotechnological structure potential benefits for detoxifying or remediating of toxic pollutants

The artificial clay nanomaterial (hydrotalcite that consists of a layered double hydroxide of Mg) doesn't need costly laboratory instrumentation for removal of arsenic constituents. Thus the filtration water for removing arsenic is percolated through hydrotalcite column. Zinc oxide nanoparticle structures could be employed for removing arsenic employing nanotechnological purification device. Nanoparticle structures of iron are that the most generally employed the set of nanomaterial structures that would be distributed for remediating pollutants in soil. Alternative nanomaterial structures that would be employed in remediating process involve nanoscale zeolite clay mineral (natural crystalline metal silicates), metal oxides, fibers, carbon nanotubes, enzymes, numerous noble metals and titanium dioxide TiO_2. Nanoparticles filter instruments are accustomed for removing organic pollutants and pesticides (like trichloroethane (DDT), Malathion, dichloro-diphenyl-endosulfan, and chlorpyrifos) from water [24].

N*anocoatings as self-sanitizing photocatalyst used in poultry houses*

Photocatalyst coatings used as self-sanitizing materials employed in poultry homes with titanium dioxide (TiO_2) nanostructures that could be involved to oxidize and destroy microorganism within the presence of light and humidity. The distinctive photocatalytic properties of the nanostructure TiO_2 are activated once the coating is exposed to sun light or UV radiation. Within the presence of humidity, TiO_2 oxidizes and destroys microorganism. Once coated, the surface remains self-sanitizing as long as there's enough lightweight to activate the photocatalytic result. Also modified nano-clays (montmorillonite nanocomposite) could ameliorate the harmful effects of some types of aflatoxin on poultry [33].

Nanotechnological structure materials and safety aspects (risk assessment)

Nanotechnology is one among the quickest growing technological fields of the 21st century. However, the success of the rising nanotechnology applications should rely upon the dynamic development of nanomaterial toxicology, risk, and exposure assessment. The objectives of the NATO (The North Atlantic Treaty Organization) and ARW (Advanced Research Workshop) were to supply an exchange of expertise in nanotoxicology and risk assessment between scientists from NATO and Partner countries, to recognize the foremost necessary gaps in knowledge, and to recognize directions for future research which could guarantee safe application and development of nanotechnology [34].

NATO general safety recommendations for nanotechnological structure materials [35]

- Potential risk: Estimation of potential risk should be an integral a part of nanotechnology development altogether countries.
- Product development: Nanotechnological product development cycles ought to combine an estimation of potential risk and risk reduction from the earliest periods.
- Strategic analysis: Organizations investment in Nanotechnology research ought to invest in strategic research to estimate potential health and environmental impact, and to develop effective risk management and risk-reduction methods.
- Information exchange: Countries investment in nanotechnology ought to partner to share data and resources once researching potential risk and developing risk-management policies.
- International harmonization: the International agreement is required on strategic risk research desires and aims.
- Multidisciplinary research: Collaboration between various scientific disciplines ought to be inspired and supported so as to develop effective risk assessment and management strategies for nanotechnologies.
- Risk communication: There should be dialogue (between government, industry, academics, nongovernmental organizations and also the public) on the advantages and risks of nanotechnology supported by relevant and high-quality science.
- Continuing education and training: International issue-specific workshops ought to be controlled to support coordinated nanotechnology risk research and policy.

***Risk assessment and management of nanomaterial* structures**

❖ **Workplace [36]**

- Methods and tools ought to be developed to recognize and characterize designed nanomaterials in biological matrices.
- Nano-specific tools for characterizing the physical and chemical properties of nanomaterials in risk research ought to be developed, through collaborations and partnerships with researchers characterizing nanomaterial practicality and pertinence.
- Novel methods of estimating potential impact in situ ought to be developed, as well as the employment of bio-monitoring and therefore the development of instruments that combine measurements of exposure with an analysis of potential hazard (such as reactive gas species, ROS, production).
- Terminology and nomenclature standards ought to be developed for nanotechnologies and nanomaterials that are specific to addressing potential impact.

❖ **Exposure study**

- Universal personal aerosols samplers ought to be developed that measure particle mass, number, and surface area concentration at the same time.
- International guidance ought to be progress on the effective exposure control of engineered nanomaterials.

❖ **Hazard/Toxicity study**

- Well-characterized stable benchmark and reference materials ought to be developed and used for toxicological studies. The applicability of those materials ought to be assessed frequently against the properties and characteristics of recently developed nanomaterials.
- Rapid cellular assays ought to be prescribed and used for screening and preliminary hazard ranking of designed nanomaterials.
- Nanomaterials should be sufficiently characterized in toxicity tests.
- The connectedness of all vital exposure routes ought to be investigated, as well as the most routes of oral, inhalation and dermal exposure.

- While in vivo tests could remain essential, alternatives ought to be developed that minimize reliance on animal testing for newly built nanomaterials.

❖ **Risk Assessment study**

- Research into assessing and managing the potential impacts of nanotechnologies within workplace might be a high priority, involving measurement employee exposure, controlling nanomaterials release, and safe disposal of nanomaterials.
- Life-cycle analysis methodologies ought to be developed for evaluating the potential collision of built nanostructured materials and products on human health and environment, from production to disposal.
- The dynamics of nanomaterials within the body and also the environment ought to be studied (including material disposition, dispersion, transformation, and accumulation).
- Data are required on human exposure, biomonitoring, and health outcomes which may be associated with exposure.

Recommendations for risk communication and management [36, 37]

Risk communication

- Education and training are required for researchers, manufacturers, and customers of nanomaterials concerning the safe development and use of nanomaterials.
- Open access to nanotechnology risk-relevant information among industries is required, as well as toxicity data, exposure data, and best obtainable operating practices.
- Clear and transparent communication with consumers is required on the potential advantages and risks of products developed employing or containing nanomaterials.
- Products that contain nanomaterials ought to clearly state on the ingredients list which components are present as nanomaterials.

Risk management

- Existing rules ought to be evaluated for their relevance applicability to designed nanomaterials, and wherever necessary new rules ought to be developed.
- Chemical regulations ought to be extended and enforced in order that MSDS (Material Safety Data Sheet) for designed nanomaterials contain correct and relevant information on potential risks of designed nanomaterials.
- International guidance ought to be developed and shared on the best available practices on the market.
- Criteria ought to be developed for once and how medical screening is conducted once exposure to designed nanomaterials doubtless happens. The recommendations consider the views of meeting participants and supply a valuable resource for developing further international collaborations and actions to confirm the potential risks of emerging nanotechnologies are assessed and managed suitably.

REFERENCES

[1] Fraceto, L. F., Grillo, R., Gerson A deMedeiros, Scognamiglio, V., Rea, G. and Bartolucci, C. (2016). Nanotechnology in Agriculture: Which Innovation Potential Does It Have?. Frontiers in Environmental Science, 4(20)1-5.

[2] Rai, M. and Duran, N. (2011). Metal Nanoparticles in Microbiology. Springer-Verlag Berlin Heidelberg.

[3] Huang, J., Chen, C., He, N., Hong, J., Lu, Y., Qingbiao, L., Shao, W., Sun. D., Wang, X.H., Wang, Y., Yiang, X. (2007) Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf. Nanotechnology, 18(10):105–116.

[4] Mishra, S., Keswani, C., Abhilash, P. C., Fraceto, L. F. and Singh, H. B. (2017). Integrated Approach of Agri-nanotechnology: Challenges and Future Trends. 8 (471) 1-12.

[5] Prasad, R., Kumar, M. and Kumar, V. (2017). Nanotechnology: An Agricultural Paradigm. Pub. By Springer Nature Singapore.

[6] Nagajyothi, P.C., Lee, K.D. (2011). Synthesis of Plant-Mediated Silver Nanoparticles Using Dioscorea batatas Rhizome Extract and Evaluation of Their Antimicrobial Activities. Journal of Nanomaterials, 2011: Article ID 573429 (7 pp).

[7] Duhan, J. S., Kumar, R., Kumar, N., Kaur, P., Nehra, K. and Duhan, S. (2017). Nanotechnology: The new perspective in precision agriculture. Biotechnology Reports, 15: 11–23.

[8] Thakkar, K.N., Mhatre, S.S., Parikh, R.Y. (2010) Biological synthesis of metallic nanoparticles. Nanomedicine, 6(2):257–262.

[9] Cheng, H. N., Doemeny, L., Geraci, C. L. and Schmidt, D. G. (2016). Nanotechnology: Delivering on the Promise Volume II. ACS Symposium Series; American Chemical Society: Washington, DC.

[10] Cao, J., Hu, X.; Jiang, D. (2009). Synthesis of gold nanoparticles using halloysites. Journal of Surface Science and Nanotechnology, 7:813–815.

[11] Balasooriya, E. R., Jayasinghe, C. D., Jayawardena, U. O., Ruwanthika, R. W. D., de Silva, R. M. and Udagama, P. V. (2017). Honey Mediated Green Synthesis of Nanoparticles: New Era of Safe Nanotechnology. Journal of Nanomaterials, vol. 2017, Article ID 5919836, 1-10.

[12] Bansal, V., Bharde, A., Ramanathan, R., Bhargava, S. K. (2012). Inorganic materials using ‘unusual’ microorganisms. Advances in Colloid and Interface Science, 179–182: 150–168.

[13] Fayaz, A.M., Balaji, K., Girilal, M., Yadav, R., Kalaichelvan, P.T., Venketesan, R. (2010). Biogenic synthesis of silver nanoparticles and their synergistic effect with antibiotics: a study against gram-positive and gram-negative bacteria. Nanomedicine: Nanotechnology, Biology, and Medicine, 6 (1): 103–109

[14] Gericke, M. and Pinches, A. (2006) Biological synthesis of metal nanoparticles. Hydrometallurgy, 83 (1–4):132–140.

[15] Riddin, T.L., Gericke, M., Whiteley, C.G. (2006). Analysis of the inter- and extracellular formation of platinum nanoparticles by Fusarium oxysporum f sp. lycopersici using response surface methodology. Nanotechnology, 17(14):3482–3489.

[16] Rai, M., Yadav, A., Bridge, P., Gade, A. (2009). Myconanotechnology: a new and emerging science. In: Rai MK, Bridge PD (eds.) Applied mycology, vol. 14. CAB International, New York, pp 258–267.

[17] Kumar, S., Amutha, R., Arumugam, P., Berchmans, S. (2011). Synthesis of gold nanoparticles: an ecofriendly approach using Hansenula anomala. ACS Applied Materials and Interfaces, 3(5): 1418–1425.

[18] Ramezani, N., Ehsanfar, Z., Shamsa, F., Amin, G., Shahverdi, H.R., Monsef- Esfahani, H.R., Shamsaie, A., Dolatabadi- Bazaz, R., Shahverdi, A.R. (2008). Screening of medicinal plant methanol extracts for the synthesis of gold nanoparticles by their reducing potential. Zeitschrift für Naturforschung B, 63(7):903–908.

[19] Shakibaie, M., Khorramizadeh, M.R., Faramarzi, M.A., Sabzevari, O., Shahverdi, A.R. (2010). Biosynthesis and recovery of selenium nanoparticles and the effects on matrix metalloproteinase- 2 expression. Biotechnol. Appl. Biochem. 56(1):7–15.

[20] Moghaddam, A. B., Moniri, M., Azizi, S., Rahim, R. A., Ariff, A. B., Saad, W. Z., Namvar, F., Navaderi, M. and Mohamad, R. (2017). Biosynthesis of ZnO Nanoparticles by a New Pichia kudriavzevii Yeast Strain and Evaluation of Their Antimicrobial and Antioxidant Activities. Molecules, 22 (872) 1-18.

[21] Hui, Y.H. (2006). Handbook of food science, technology, and engineering. vol. 4, CRC Press, Taylor & Francis Group.

[22] ImranDin, M. I. and Rehan, R. (2017). Synthesis, Characterization, and Applications of Copper Nanoparticles. Journal of Analytical Letters, 50 (1) 50-62.

[23] He, S., Guo, Z., Zhang, Y., Zhang, S., Wang, J., Gu, N. (2007). Biosynthesis of gold nanoparticles using the bacteria Rhodopseudomonas capsulata. Materials Letter, 61 (18):3984–3987.

[24] Tiwari, M., Sharma, N. C., Fleischmann, P., Burbage, J., Venkatachalam, P. and Sahi, S. V. (2017). Nanotitania Exposure Causes Alterations in Physiological, Nutritional and Stress Responses in Tomato (Solanum lycopersicum). Frontiers in Plant Science, 8(633) 1-12.

[25] Ayangbenro, A. S. and Babalola, O. O. (2017). A New Strategy for Heavy Metal Polluted Environments: A Review of Microbial Biosorbents. Int. J. Environ. Res. Public Health, 14 (94) 1-16.

[26] Brock, D. A., Douglas, T.E., Queller, D.C., Strassmann, J.E. (2011). Primitive agriculture in a social amoeba. Nature 469: 393-396.

[27] Qu, L., Xia, S., Bian, C., Sun, J., Han, J. (2009). A micro-potentiometric hemoglobin immunosensor based on electropolymerized polypyrrole-gold nanoparticles composite. Biosensors & Bioelectron, 24(12):3419–3424.
[28] Aragay, G., Pino, F., Merkoci, A. (2012). Nanomaterials for sensing and destroying pesticides. Chemical Reviews, 112: 5317–5338.
[29] Vidhyalakshmi, R., Bhakyaraj, R., Subhasree, R.S. (2009). Encapsulation the future of probiotics-A Review. Adv. Biol. Res. 3(3-4):96-103.
[30] Young, K.J. (2009) Antifungal activity of silver ions and nanoparticles on phytopathogenic fungi. Plant Dis. 93(10):1037-1043.
[31] Kim, S.W., Jung, J.H., Lamsal, K., Kim, Y.S., Min, J.S., Lee, Y.S. (2012). Antifungal effects of silver nanoparticles (AgNPs) against various plant pathogenic fungi. Mycobiology, 40(1):53-58.
[32] M.A.Shah, A. Towkeer. (2010). Principles of Nanoscience and Nanotechnology, Naroosa Publishing House, New Delhi.
[33] Prasad, R., Kumar, V. and Prasad, K. S.(2014) Nanotechnology in sustainable agriculture: Present concerns and future aspects. African Journal of Biotechnology, 13(6): 705-713.
[34] Wright, F. A. P. (2017). Potential risks and benefits of nanotechnology: perceptions of risk in sunscreens. MJA, 204 (10) 396-371.
[35] Stone, V., Pozzi-Mucelli, S., Tran, L., Aschberger, K., Sabella5, Ulla Vogel, S., Poland, C., Balharry, D., Fernandes, T., Gottardo, S., Hankin, S., Hartl, M. G. J., Hartmann, N., Hristozov, D., Hund-Rinke, K., Johnston, H., Marcomini, A., Panzer, O., Roncato, D., Anne –Saber, T., Wallin, H. andScott-Fordsmand, J. J. (2014) ITS-NANO - Prioritising nanosafety research to develop a stakeholder driven intelligent testing strategy. Particle and Fibre Toxicology, 11(9) 1-11.
[36] Sadeghi, R., Rodriguez, R. J., Yao, Y. and Kokini, J. L. (2017). Advances in Nanotechnology as they Pertain to Food and Agriculture: Benefits and Risks. The Annual Review of Food Science and Technology, 8(21): 1–26.
[37] Sharma, V.K, Yngard, R.A., Lin, Y. (2009). Silver nanoparticles: green synthesis and their antimicrobial activities. Adv. in Colloid and Interface Sci. 145(1-2):83–96.