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A REVIEW ON GREEN SYNTHESIS OF PLATINUM NANOPARTICLES

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Abstract

Platinum nanoparticles (PtNPs) have a variety of beneficial applications in the domains of medicine and the environment, making them an exciting and fascinating research topic. The goal of current research is to provide a route in order to synthesise platinum nanoparticles that is environmentally sustainable as well as cost-effective. Physical-chemical approaches of Pt NP synthesis have been improved by bio-fabrication protocols based on bacteria, fungi, and plant extract. In comparison to other biological synthetic approaches like bacteria and fungi, this review article addresses the methods in which platinum nanoparticles can be synthesised by various plant extracts as this method does not involve any time-consuming culturing and preservation. Furthermore, platinum nanoparticles produced from plant extract are more stable, precise and efficient and can easily modify in various shapes and sizes. Extracts of various plants like *P. salicifolium*, *Tragia* involucrata leaf extract (Ti-PtNPs), almond skin extract, zahidi dates, *Atriplex halimus* leaf, *Prosopis farcta* fruit, *Phoenix dactylifera* L.'s Anbara fruit *Rumex dentatus* seeds have been successfully employed for the synthesis of platinum nanoparticles.

Keywords: Nanotechmology:green approches:platinum nanoparticles

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1. Introduction:

The term "nanotechnology" " is about the creation and use of ingredients whose components, as a rule, have a size of up to 100 nm and may be seen at the nanoscale. Nanotechnology studies magnetic, optical, and electrical phenomena by analysing structural behaviour at the molecular and sub-molecular levels. In recent years, nanoparticles have grown in importance across a wide range of industries, including energy, health care, environment, agriculture etc. (Saba, 2014) In the past several years, research and development in the area of nanotechnology have grown rapidly across the globe. (Usman et al., 2019) Currently, a global assessment of recent innovations shows a great deal of interest in the nanotechnology sector. This interest was sparked by a variety of peculiar chemical and physical characteristics of materials at the nanoscale level, including a high ratio of surface to volume and an increase in surface action as compared to their bulk products with the same composite. (Usman et al., 2019)

1.1 Structure of nanoparticles:

Nanoparticles are three-layered molecules, unlike simple molecules: (a) The surface layer can be synthesized and characterized with a diverse range of tiny molecules, metal ions, detergents, and polymeric materials. (b) The core is the NP's centre section and often corresponds to the NP itself.; (c) In all aspects, the shell layer is a chemically separate substance from the core. (Shin et al., 2016)

Numerous types of noble metal nanoparticles like as platinum, gold, palladium, and silver have been demonstrated in the fields of healthcare, chemistry, along with material science. (Jameel et al., 2020) A 20-nm platinum (Pt) NPs have characteristic yellowish grey colour. (Dreaden et al., 2012) Platinum nanoparticles (Pt NPs) have drawn the most attention among these nanoparticles due of their peculiar structural properties, optical activities, enzymatic actions, and large surface area characteristics, as well as their remarkable corrosion resistance, making them a prospective choice for catalytic reactions and biomedical sciences. (Dong et al., 2021) Pt NPs were thought to be effective and capable of acting as medication carriers. (Barua & Mitragotri, 2014) Pt NPs also have a variety of medical applications, including those for the treatment of cancer, diabetes, germs, and fungi (Naseer et al., 2020)

2. Synthesis of Platinum Nano particles

Several techniques have been used to create stabilised noble metal NPs. These techniques are mainly divided into

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top-down and bottom-up processes **(Fig.1.).** Nanosized assemblies were created using the bottom-up approach

from molecular building blocks. The dedicated microscopic machine is used in the top-down approach to create nanoparticles from their constituent metals and scale them down to nanoscale dimensions

PtNPs' form, size, electronic surface, elemental assembly, and capping agents have a significant impact on their biological and industrial uses, which motivates researchers to create and use innovative synthetic processes to enhance these aspects. PtNP manufactured for biomedical applications is largely influenced by their physicochemical characteristics, dispersion, and stability in a biological setting, as these aspects are crucial in characterising the amount of their toxicity. Fig.1. depicts various methods for synthesising PtNPs, including mechanical, chemical, physical, and biologically assisted techniques.

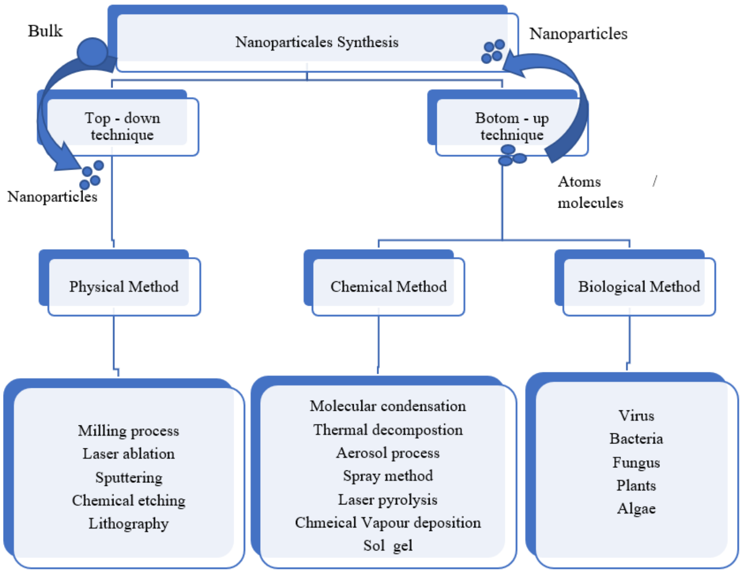

Fig.1. Several methods for synthesis of PtNPs

2.1 Physical methods:

Physical methods including flame synthesis, [22] electron beam induced reduction, [23] laser ablation, [24] and aerosol-assisted deposition [25] are currently gaining a lot of attention in an effort to resolve some of the shortcomings of chemical techniques (such as solvents that are organic, lethal reagents, etc,).A high-intensity laser beam is utilized during the laser ablation procedure to solubilize Pt NPs from a solid source. A laser beam can be employed in both steady and cyclic modes. This adaptable approach uses temperature fluctuation, vibrations, and ambient pressure variations to determine the characteristics of PtNPs. (Dhand et al., 2015) This approach of PtNPs fabrication is not widely utilized due to the high dilution and problems that might arise while calibrating the size, scale, shape, and yield of the PtNPs. (Scaramuzza et al., 2016) Furthermore, the stability of these PtNPs inside a biological process may offer certain complications.

2.2 Chemical methods:

Within chemical approaches, galvanic displacement (Mahmoud et al., 2010) chemical vapour deposition, wet chemical reduction (WCR) (Bönnemann & Richards, 2001) and electrochemical reduction (Mahima et al., 2008) have recently sparked interest in influencing the physicochemical features during chemical treatments of platinum nano particles. To acquire greater control of the reaction conditions, multiphase synthetic setups have also been established, incorporating the use of lowering agents in the gaseous state. (Zhou et al., 2013) The usage of large quantities of chelating agent, cleansers, and liquid hydrocarbons, that might impact the toxicity of NPs is a major drawback of this method for producing PtNPs. Furthermore, its extensive expansion may pose environmental problems. Glycerol as well as microwaving (as both a solvent and a reducing agent) have been advised to minimize the adverse impacts on the environment and to increase industrial scale-up.(Nirmala Grace & Pandian, 2007) (Kou et al., 2013) Because very hazardous chemicals and solvents were used in the traditional chemical production of Pt NPs was neither energy efficient nor environmentally beneficial.

Table 1: Advantages and Disadvantages of various methods used for synthesis of Pt NPs.

Methods	**Merits**	**Demerits**
Physical method	Rapid, no use of harmful chemicals, purity, consistent size and shape	Efficiency, expensive demand, radiation exposure, high energy, temperature, and pressure requirements, huge volume of waste generation, high dilution, challenging size and shape tunability, poorer stability, modified surface chemistry, and physicochemical features of nanoparticles.
Chemical method	Cost-effective, high surface chemistry diversity, simple functionalization, high yield, size flexibility, heat resistance, and decreased dispersity	Low purity, usage of harmful toxins and organic solvents, endangering to both humans and the environment.
Using Plants extract	Simple, convenient to use, nontoxic, and biocompatible.	Size, shape, and crystal development are difficult to manage. Stability and aggregation

2.3 Bio fabricated synthesis of platinum nanoparticles

Physical-chemical approaches of Pt NP synthesis have been improved by bio-fabrication protocols based on bacteria, fungi, and plant extract. It is economical, environmentally benign, and simple to enhance production of extremely stable nanoparticles on a big scale. The objective of this research is to create an economical, environmentally sustainable, and one-step green synthesis of Pt NPs.

2.4 Fungal synthesis of platinum nanaoparticles

The fungus F. oxysporum was utilised in extracellular biosynthesis and comprehensive analysis of platinum nanoparticles that are water dispersible and protein encapsulated. The mould stabilises the produced nanoparticles by reducing hexachloroplatinic acid (H_2PtCl_6) in solution form by depositing proteins at room temperature. The produced nanoparticles were discovered to have a peculiar shape that is sphere-shaped and around 15–30 nm in size. Most crucially, this technique produces nanoparticles that are enclosed by fungus-secreted natural proteins; these do not require the addition of any artificial stabilisers, most of which are harmful. Fungus is a great choice for bio fabrication of nanoparticles synthesis because it considerably boosts production also it ensures protein coating and stability while also preventing particles clumping together. (Syed & Ahmad, 2012)

2.5 Algal synthesis of platinum nanoparticles

Algae extracts are rich in biomolecules that can reduce metal ions and cap them to make them more biocompatible. Regarding the utilisation of algae in the manufacturing of platinum nanoparticles, the antibacterial and anticancer properties of substances such as Flavonoids, terpenoids even alkaloids can have a significant real impact. Thus, *Botryococcus braunii*, a green alga, provided PtNPs. Bio reduction is caused by polypeptides, carbohydrates, amides, as well as long chain fatty acids, which act as covering but also stabilising factors., according to FTIR study data. Platinum ions were reduced using proteins and sugars that is (Pt) to platinum nanoparticles (PtNPs) according to the platinum nanoparticle study of the brown seaweed *Padina gymnosporia.* The red algae *Halymenia dilatate* aqueous extract contained terpenoids, glycosides, tannins, alkaloids, steroids, carbs, flavonoids, amino acids, and polypeptide. These compounds can be connected to the surface of platinum nanoparticles via functional groups and aid to minimise free metal ion inside the nanoparticle and stabilise it by covering it.(Fenoradosoa et al., 2012) This was the first time, PtNPs have been produced from *H. dilatata* extract, and their diverse biological properties were identified. Spectral analysis and microscopic examination were used to confirm the production of Hd-PtNPs. Hd-PtNPs generated show exceptional antioxidant, cytotoxic, but also antimicrobial activities. Hd-PtNPs showed an IC50 value of 50 g/mL over MDA-MB-231. However, they outperformed S. pneumonia in terms of antimicrobial property towards A. hydrophila. Moreover, the toxicity results showed that HdPtNPs do not cause substantial fatality in Artemia nauplii, showing that biosynthesized NPs are safe. As a result, the synthesizing approach for Hd-PtNPs is minimal, ecologically responsible, and demonstrates a wide spectrum of biological activities, implying that they may be useful for biomedical and pharmaceutical purposes. (Sathiyaraj et al., 2021)

2.6 Bacteriogenic platinum nanoparticles

Even though bacteria are selective, nanoparticles can be developed from impure starting feeds., bacterial manufacture of nanoparticles (NPs) might possibly cut production costs while simultaneously decreasing starting material prices**.**(Edmundson et al., 2014) Platinum (Pt) nanoparticles were produced using a bacterial cellulose matrix and a potassium tetrachloroplatinate (K_2PtCl_4) precursor solution (BC). By using a hydrogen gas reductant to reduce the preliminary solution, Pt nanoparticles are formed at the surface and interior of the BC membrane. Researchers have used scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), thermogravimetry study and X-ray diffraction (XRD) were used to investigate the creation of Pt nanoparticles resulting from alterations in precursor concentrations (between 3.0 mM to 30 mM). Pt particles have diameters ranging from 6.3 nm to 9.3 nm on the basis of X-ray diffraction data, and Pt particle size rises with precursor concentration. SEM-EDS were utilized to investigate overall morphology of Pt nanoparticles**.** (Aritonang et al., 2014)

2.7 Synthesis of platinum nanoparticles using plant extracts

In comparison to other biological synthetic approaches, plants are preferred because they avoid the requirement for prolonged bacterial and fungal preservation and culturing. Extracellular plant extracts have also been shown to be more efficient and precise in altering nanoparticle size, shape, and dispersity (Muthu & Priya, 2017) As a result, using botanicals in the production of nanoparticles promotes green chemistry concepts such as less harmful chemical synthesis, nontoxic solvents and additives, design for energy efficiency and use of renewable resources. NPs have also been produced using plant parts such roots, leaves, stems, and fruits since their extract contains phytochemicals like flavonoids, tannins, and phenolic compounds that act as both a reducing and preservative agent (Rajeshkumar, 2016) Plants are used to produce Pt NPs since they are easier, smoother, more persistent, affordable, and create more reliable synthetic nanoparticles than other, conventional methods. (Atta et al., 2020)

2.7.1. Polygonum salicifolium leaves

P. salicifolium leaf aqueous extract was employed to make platinum nanoparticles (PS-PtNPs) in a quick, simple, and affordable manner. Several methods were used to characterise PS-PtNPs, including UV-Visible, X- ray Photoelectron Spectroscopy, Energy Dispersive X-ray spectroscopy, X-ray diffraction, , EDX elemental mapping, Zeta Potential, High resolution Transmission Electron Microscope, Selected Area Electron as well as FT-IR. Synthesised PS-PtNPs had a brown tone and a nearly spherical form, and they ranged in size from 1 to 3 nm. Furthermore, the synthesised PS-PtNPs showed total zeta voltage at - 25.9 mV., which was supported by the fact that they had been steady for almost 90 days. The ability of PS-PtNPs to quickly catalytically degrade (MB) methylene blue at various doses up to 100 mg/L demonstrated their superiority as a catalyst. The inhibitory effect of PS-PtNPs over gram-negative bacteria was fairly strong. Additionally, anti-diabetic along with effective antioxidant activities have also been demonstrated by PS-PtNPs. These findings suggest a viable route for the bioactive production of PtNPs using an aqueous leaf extract from P. salicifolium. (Hosny et al., 2022)

2.7.2 Almond skin extract

The goal of the current work has been to enhance the production of platinum nanoparticles that are biodegradable and seem to have potential to catalyze the reaction, enzyme-mimicking, but also have antioxidant properties produced by food waste almond skin extract. The ideal situation for the reaction were 10 mM of precursor in a 2:1 extract-to-water ratio, pH 9, and 14 minutes at 90°C, according to the optimization of reaction conditions. After being characterised using various spectroscopic and imaging approaches, size of Pt-NPs were found to be 6-8 nm and they are irregularly shaped and have face centred cubic arrangement also they are negatively charged. Platinum nanoparticles demonstrated the highest degree of catalytic efficiency when they reduced 4-nitrophenol by 90.39% in 16 minutes. The reaction exhibited pseudo-first order kinetics when there was 30 ppm of 4-nitrophenol, 0.6 mg/mL of catalyst, and pH 10. Additionally, 3.83 g/mL/min of amylase-mimicking activity was observed in platinum nanoparticles. Furthermore, platinum nanoparticles demonstrated substantial antioxidant properties in a dose-dependent manner, indicating that they may be effective antioxidant agents. Peripheral blood mononuclear cells were examined for cytotoxicity and found to be unaffected when subjected to comparatively high levels (100 g/mL) of PtNP, indicating acceptable biocompatibility. In light of this, the current study successfully demonstrated the use of almond skin extract as a wasted food for such bioactive manufacture of nontoxic platinum nanoparticles with bioactivities . (Sadalage et al., 2022)

2.7.3 Rumex dentatus seeds

The first acid phosphate assisted platinum nanoparticles (ACP-PtNPs) were created by extracting the acid phosphatase from Rumex dentatus seeds. The durability and encapsulation of ACP-PtNPs had been investigated. significantly aided by acid phosphatase. Numerous methods were used to characterise the ACP-PtNPs, including DLS analysis, HRTEM, XRD, SEM, XPS, EDS, FTIR and UV-visible spectroscopy. Brown in complexion but usually shape is spherical, ACP-PtNPs had very tiny particle sizes (1–7 nm). ACP-PtNPs' production was verified by the appearance at 295 nm of a plasmonic peak. The as-prepared nanoparticles were evaluated for their ability to photocatalytically degrade methylene blue (MB), under visible light irradiation. The outcomes demonstrated that ACP-PtNPs had exceptional photocatalytic effectiveness by destroying 99% of MB in just 28 minutes. Additionally, ACP-PtNPs demonstrated high photoinhibition effectiveness against Bacteria that are Gram-negative. In the cytotoxicity study, ACP-PtNPs were shown to be non-toxic towards perfectly functioning RBCs. Importantly, remarkable antioxidant properties have been sown by ACP-PtNPs, also efficiently neutralizing eighty-eight percent of the toxic 1,1-diphenyl-2-picrylhydrazil (DPPH) radical. The compact size along with substantial surface area of ACP-PtNPs may be accountable for their remarkable photocatalytic and biological activities. (Rehman et al., 2022)

2.7.4 Prosopis fracta fruit

The use of contrast chemicals can improve computed tomography (CT) imaging. The commonly used therapeutic small-molecule zagents (Omnipaque) have a number of limitations, including the possibility of harmful and undesirable side effects. Therefore, to enhance overall Hounsfield (HU) scores during CT imaging this work provides a simple method for synthesising platinum nanoparticles (Pt NPs) with the assistance of plants. The average diameter is 3.8 nm., these "one-step, one-pot," eco-friendly, and straightforward Pt NPs colloidal were very stable, biocompatible, and extremely tiny. Fruit extract of Prosopis farcta (P. farcta) was employed as a stabiliser as well as reductant. The cell viability test revealed that high Pt NP concentrations still have no influence on HEK-293 cell viability. The as-synthesised Pt NPs (HU = 355) had a higher X-ray attenuation than commercial NPs and traditionally prepared NPs. As a result, this study offers fresh perspectives on the preparation of new molecular imaging contrast agents using plants. (Jameel et al., 2021)

2.7.5 Zahidi dates

By using an extract of Zahidi dates, platinum nanoparticles (Pt NPs) were created via a green synthesis process. Platinum salts were efficiently reduced to their corresponding Pt NPs in the presence of dissolved dates extract, that is considered to be a rich source of phytonutrients which aided to convert Pt^{+4} to Pt° ions by supplying electrons for all these atoms. The nanoparticles were characterised using many methods. According to TEM examination, the Pt NPs were present in sizes between 30 and 45 nm. Nanoparticles with spherical forms can be seen in FE-SEM pictures. Platinum nanoparticles showed a narrow size distribution, according to AFM screening. The XRD diffraction study demonstrated that the creation of Platinum nanoparticles has a face-centered cubic crystalline arrangement. when compared to the conventional validated range of Platinum particles obtained throughout the tests. The FT-IR spectroscopy spectrum revealed a number of peaks in the range of (400–4000) cm^{-1}, which were utilised to pinpoint the functional groups in charge of Pt NPs' capping and reducing. Cancer cells from the SKO-3 cell line for ovarian cancer and the SK-GT-4 cell line for oesophageal cancer had been subjected to a different concentration of generated platinum nanoparticles, as well as the frequency at which the proliferation of the cells was inhibited after 7 days. Cytotoxicity examination revealed that the cancer cells were subjected to a very harmful impact. Pseudomonas aeruginosa, a gram-negative bacterial species, and Streptococcus pyogenes, a gram-positive bacterial species, had been subjected to various concentrations of produced platinum nanoparticles The results showed a sizable amount of inhibitory action, and concentration-dependent suppression of bacterial growth was observed. (Ali & Mohammed, 2021b)

2.7.6 Tragia involucrata

The goal of this work is to create platinum nanoparticles with medicinal potential for therapeutic systems derived by Tragia involucrata leaves extract (Ti-PtNPs). Artificially created Ti-PtNPs exhibit 10 nm-sized, spherical-like particles. Ti-PtNPs demonstrated stronger antioxidant capacity than AE-Ti but also antimicrobial properties in agar bioassay, disc migration, and mortality rates. The Ti-PtNPs also adhered to the bacterial outer cell membrane and boosted polypeptide permeability efficiency. IC50 is 27.72 g/ml for Ti-PtNPs against HeLa cells indicated their strong cytotoxicity. Additionally, Ti-PtNPs increase the production of cytoplasmic ROS, which leads to mitochondrial mortality. Due to their fabrication, Ti-PtNPs can be used in a wide range of health-care applications. (Selvi et al., 2020)

2.7.7 Atriplex halimus leaf

Atriplex halimus leaf aqueous extract was used as a reductant to create green platinum nanoparticles (PtNPs). Platinum nanoparticles made of atriplex (At-PtNPs) remained sustained for at least 90 days. As a result of their ability to catalytically breakdown MB dye, Effective catalyst, another remarkable property has been shown by At-PtNPs as well as they also demonstrated significant antimicrobial activity. At-PtNPs were demonstrated to be a very effective antioxidant. Thus, employing Atriplex halimus aqueous extract, the obtained results present a feasible approach for the green production of PtNPs. (Eltaweil et al., 2022)

2.7.8 Phoenix dactylifera Linn

Phoenix dactylifera L.'s Anbara fruit is used to make synthetic platinum nanoparticles (PtNPs), which are then examined utilising a variety of spectroscopic analytical techniques These PtNPs were used to evaluate both hepatotoxic as well as hepatoprotective consequences of severe liver injury induced via CCl4 on Wister rats. For the purpose of determining the harmful effects on the rats' important organs, histopathological analyses were carried out. Several liver biomarker catalysts alanine transferase (ALT), aspartate amino transferase (AST), and alkaline phosphatase (ALP) were found in organs like as the kidney, gut, even liver. Comparing the experimental results to those of the reference medication Silymarine, significant findings were made. It has been demonstrated that the Wister rat liver enzymes are protected by PtNPs and AAE. (Al-Radadi & Adam, 2020)

2.7.9 Nigella sativa Linn

Here, seed extract of black cumin (Nigella sativa L.) was employed as a reductant to create biofabricated platinum nanoparticles (Pt NPs). Pt nanoparticles possess globular shapes with diameters ranging from 1-6 nm, according to TEM examination. Additionally, Overall cytotoxicity by biogenic Pt NPs against the MDA-MB-231 mammary and HeLa cervix carcinoma lines, as well as potential antimicrobial activity towards specific genotypes both gram-positive or gram-negative bacteria, were evaluated. The results of the microbiological and cytotoxicity tests demonstrated the efficiency of the biogenic Pt nanoparticles. both shown dose-dependent toxic effects. Findings support the growth That pharmacy sector is a promising source of antimicrobial and antitumor drugs. (Aygun et al., 2020)

2.7.10 Salix Tetraspeama Leaf

In the current study, microscopic Platinum (Pt) nanoparticles (NPs) had been successfully synthesized employing green and biogenic processes using leaf extract of Salix Tetraspeama (STL) reductant along with encapsulating agent. As a result of complete optimization of the Pt NP synthesis's effective parameters, modest sizes in the nanoscale area were achieved. The acquired findings from the synthesis revealed that the Pt NPs made possible by the ultrasonic approach are smaller than 12 nm and have improved optical, structural, morphological, anticancer, along with photocatalytic capabilities. More specifically, large levels of free radical scavenging activity were computed, as evidenced by 69% of 100 g/mL for the DPPH radical test plus its MTT assay's 85.75% in vitro detection of human mammary tumor cell line antitumor action MCF-7. Additionally, under Methylene Blue (MeB), the Pt catalytic reduction's effective parameters were totally tuned, and a greater degradation efficiency of 90% was noted. This characterisation offers a regulated, environmentally friendly, and biologically PtNPs of lower sizes have been synthesized, while their properties have been modified in a variety of applications, particularly cancerous cells. The pharmaceutical industry's drug delivery systems, and catalytic activities. (Ramachandiran et al., 2021b)

2.7.11 Combretum erythrophyllum (CE) plant

For the first time, a simple, environmentally friendly, economically advantageous, production of bio fabricated platinum nanoparticles (PtNPs) utilising Combretum erythrophyllum (CE) plant leaf extract method was demonstrated. CE extraction acted as a bio-reductant and a stabilizer. The HR-TEM picture demonstrated that the PtNPs had a nanoparticle dimension approximately 1.04 0.26 nm on average, they are extremely tiny, spherical, and well scattered. At MICs of 3.125 g/mL and 1.56 g/mL, respectively, the PtNPs demonstrated strong antibacterial action over Gram-negative Klebsiella oxytoca , Klebsiella aerogenes , also hazardous Gram-positive Staphylococcus epidermidis . The Klebsiella species that cause nosocomial infections were the ones wherein all CE-stabilized PtNPs responded best. (Fanoro et al., 2021)

2.7.12. Xanthium strumarium leaf

The utilization of an extraction in the production of platinum nanoparticles (PtNPs) from Xanthium strumarium leaf is touted as a bio-synthetic, environmentally friendly process. The synthetic process just requires one step and would not necessitate the application of capping or reducing agent. By using TEM, FT-IR, , SEM-EDAX, UV-visible spectroscopy along with PXRD, examination, the produced nanoparticles had been thoroughly characterised. The purity, size, and form were all carefully examined. TEM analysis identified a sample with a mean size around 22 nm of produced nanoparticles, and these particles have parallel lines that should be present in a flawless crystal lattice. SEM examination made it abundantly evident that the produced nanoparticles have a smooth surface and a cubic to rectangular shape. The nanoparticles also displayed a substantial cytotoxic impact on HeLa carcinoma cell lines, having overall IC50 level of 90 g/ml/24 h using the MTT experiment. Other biological profiles, such as in vitro antimicrobial activity plus antifungal efficiency in vitro, were also examined and demonstrate d the biological profile's significance. (Kumar et al., 2019)

Table 2. Plant Mediated synthesis of Pt-NP's

S.No	**PLANT NAME**	**SIZE**	**SHAPE/ COLOUR**	**EXTRACT**	**REFERENCE**
1	**Polygonum salicifolium**	1-3 nm	Spherical /dark brown	*leaf*	(Hosny et al., 2022)
2	***Prunus dulcis***	6-8nm	Irregularly shaped/ black	*almond skin*	(Sadalage et al., 2022)
3	***Rumex dentatus***	$1-7nm$	Spherical/ brown	*seeds*	(Rehman et al., 2022)
4	***Prosopis fracta***	$3.8nm$	Spherical	*Fruit*	(Jameel et al., 2021)

5	***Zahidi dates***	$30 - 45nm$	Spherical		(Ali & Mohammed, 2021b)
6	***Tragia involucrata***	$10nm$	Spherical	Leaves	(Selvi et al., 2020)
7	***Atriplex halimus***	$1 - 3nm$	Spherical/ black	*Leaves*	(Eltaweil et al., 2022)
8	***Phoenix dactylifera linn***	$2.3 - 3.0nm$	Quassi-spherical	*Fruit*	(Al-Radadi & Adam, 2020)
9	***Wigella sativa linn***	$1 - 6nm$	Spherical	*Seeds*	(Aygun et al., 2020)
10	***Salix tetraspeama***	$< 12nm$	Spherical	*Leaves*	(Ramachandiran et al., 2021a)
11	***Combretum erythrophyllum***	$1.04 - 0.26nm$	Spherical	*Leaves*	(Fanoro et al., 2021)
12	***Xanthinum strumarium***	$22nm$	Cubic/ rectangular	*Leaves*	(Kumar et al., 2019)

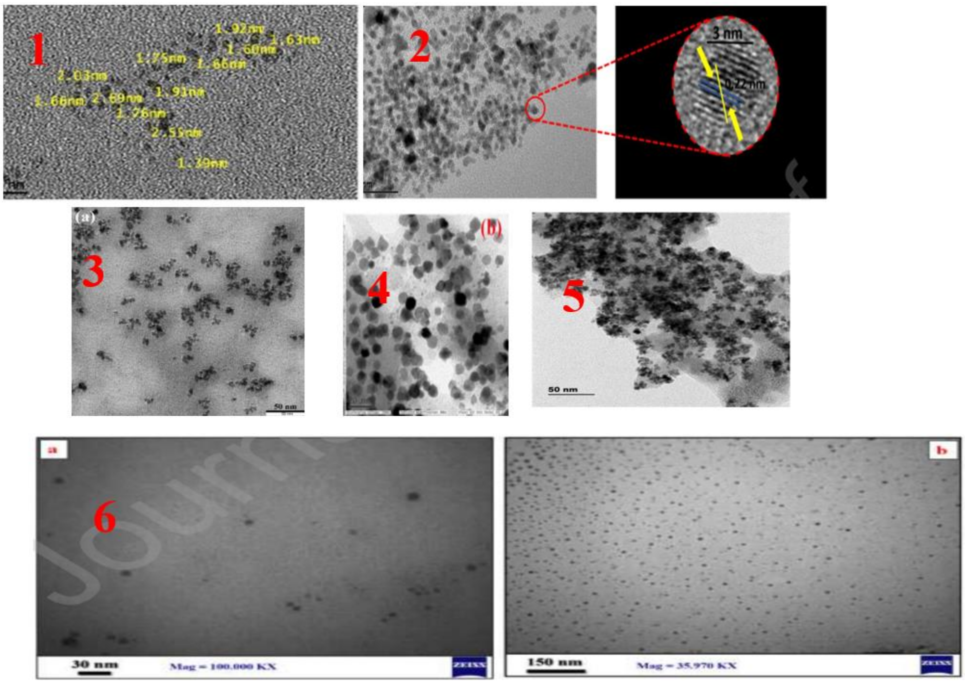

Fig.2. Morphologies of plant mediated nanoparticles.

1 HRTEM image of At-PtNPs (PtNPs by Atriplex halimus aqueous extract. (Eltaweil et al., 2022) **2** TEM image and HRTEM image of Biogenic platinum nanoparticle using black cumin seeds (Aygun et al., 2020). **3**. Representative morphological and structural images of TEM (a) and the size distribution of Pt NPs colloidal with mean diameter 3.8 nm (using prosopris fracta extract) (Jameel et al., 2021) **4** TEM-SAED pattern of Pt NPs using STL (Salixtetrasperma leaf) as extract (Ramachandiran et al., 2021b). **5** Morphological characterization of Tragia involucrata mediated platinum nanoparticles. (Selvi et al., 2020) **6** TEM micrograph Pt NPs (a) 30 nm and (b) 150 nm (Biogenic Pt NPs using Iraqi Zahidi Dates extract) (Ali & Mohammed, 2021b)

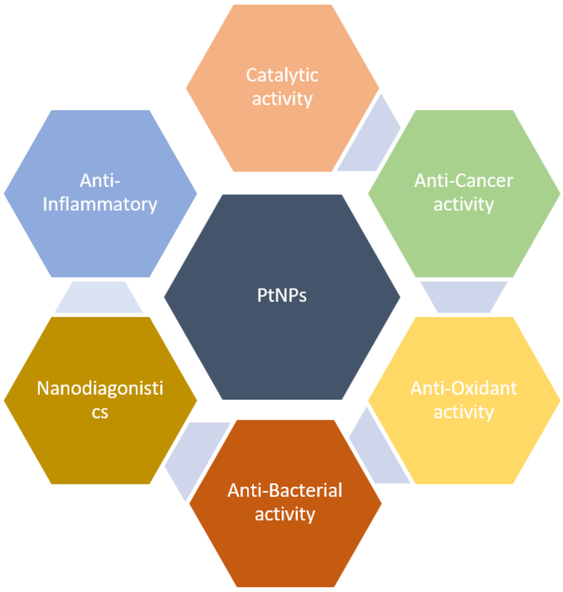

Fig. 3. Biomedical applications of PtNPs

3. Applications of Plant Mediated Pt NP's

3.1 Catalytic activity

The textile industry's emission of hazardous dyes, particularly into aquatic areas, is a major environmental problem.(Arul et al., 2021) (Eltaweil et al., 2021) Methylene blue (MB), a popular toxic dye, prevents sunlight from reaching a water body, having a long-term deleterious influence on the aquatic ecology. (Eltaweil et al., 2021) Pt nanoparticle's synthesised from leaf extract of polygonum salicifolium (PS-PtNPs) have capacity to rapidly catalytically breakdown (MB) methylene blue at different dosages up to 100 mg/L established their superiority as a catalyst. Furthermore At 25 C, 100 *L of At-PtNPs at a concentration of 50 *g/mL were added to the mixture with continuous stirring. The process was monitored by taking time-dependent UV-Vis absorption spectra of these combinations at 664 nm. Results shown catalytic breakdown of MB dye hence At-PtNPs were proven to be an excellent catalyst.

3.2 Anti-oxidant activity/Anti- bacterial activity

Bacterial strains are believed to cause a broad variety of potentially fatal infections in humans and animals. (Selvi et al., 2020)(Omer et al., 2021) Strains of bacteria, either gram-negative or gram-positive bacteria, like Escherichia coli and Staphylococcus aureus, that are often found in the environment, foodstuffs, and the guts of humans and animals (Hussain et al., 2019) potentially lead to severe skin infections, urinary and respiratory tract disorders, and intravenous catheters, specifically in immuno-suppressed people (Palareti et al., 2016) Several antibiotics were used to treat these harmful bacteria, but their continued use or ingestion led in the creation of drug-resistant bacteria. (Allen et al., 2010) Thus, innovative materials like Pt NPs must be manufactured and applied in such a difficult endeavour. (Wang & Lippard, 2005) Nanoparticles' antibacterial action is centred on their compact size and enormous surface area. Due to their tiny size and huge surface area, nanoparticles can permeate biofilms and bacterial cell membranes, influencing intracellular processes. Pt NPs enter cells by diffusion and settle in the cytoplasm. Exposure to Pt NPs also enhanced DNA damage, cell aggregation, and cell death. (Gopal et al., 2013) (Ruiz et al., 2020) Platinum has a high level of potency against several bacterial pathogens in humans. The agar-well diffusion technique was used to evaluate the effectiveness of Pt NPs as antibacterial medicines. Pt NPs at various concentrations were applied to Gram-negative bacterial strain P. aeruginosa and Gram-positive bacterial strain S. pyogenes, revealing inhibitory zones of varying sizes. The effect of Pt NPs at different concentrations on Gram-negative bacterial strain P. aeruginosa and Gram-positive bacterial strain S. pyogenes bacteria exhibited considerable growth inhibition with increasing dosage concentration. (Aygun et al., 2020)

3.3 Anti-cancer activity

3.4 Cancer is an illness that has a huge global effect. As reported by the National Cancer Institute (NCI), around 1.700.000 new instances of cancer were identified in the United States in 2016, and 595,690 persons died as a result of this disease.

3.5 Bacterial opportunistic infections are one of the most common causes of death in cancer patients. Chemotherapeutic medications enhanced the frequency of cancer remission and lengthened patient longevity, but they also raised the danger of infection. (Ruiz et al., 2020)

3.6 After breast cancer, ovarian cancer is the second most prevalent cancer in women over the age of 40. Many cytotoxic drugs are resistant to the SKO-3 human Ovarian cancer cell line. (Paramee et al., 2018) Moreover, oesophageal cancer is among the most often diagnosed cancers and the leading cause of cancer mortality. (Wong et al., 2018) SK-GT-4 is an Oesophageal adenocarcinoma cell line. Drugs like cisplatin are not only toxic to cancer cells, but also to mammalian cells. As a result of its minimal toxicity and imaging characteristics, greenway's platinum nanoparticles are a good choice. (Abbas & Krasna, 2017) The primary goals of new therapeutic experts are to develop anticancer therapeutic agents and to combat the negative effects of chemotherapy. The efficacy of Pt NPs produced from Zahidi date extract to inhibit cancer cells in humans was investigated.(Paramee et al., 2018) .Anticancer activities are carried out for 72 hours employing the aberrant cell lines SKO-3 Ovarian cancer cell line and SK-GT-4 Oesophageal cancer cell line using the MTT technique. To investigate the effects of Pt NPs on the cancer cell lines SKO-3 and SK-GT-4. The anti-proliferative effect of Pt NPs on the human SKO-3 Ovarian cancer cell line and the SK-GT-4 Oesophageal cancer cell line was investigated. The cytotoxicity of Pt NPs on the human cancer cell lines SKO-3 and SK-GT-4 after 72 hours was investigated. The results demonstrated that cell growth in cell lines was significantly suppressed. Furthermore, the suppression of cell growth increased dramatically with concentration. (Ali & Mohammed, 2021a)

4. Conclusion and Future Prospects

PtNPs are renowned for being one of the important critical players in fields of research and technology. They have sparked a lot of interest in the biomedical area due to their peculiar characteristics, which support their successful usage as medications, nano-diagnostic tools, and nano-vehicles for targeted drug administration. An extensive analysis of biological (plant, fungus, and bacterial) green methods is offered in this review, which also covers the most recent research on a variety of synthesis techniques for PtNPs, including chemical and physical methods. The chemical and physical routes, which are the traditional techniques of producing PtNPs, are regarded as hazardous and less suited for biomedical applications than green synthesis when weighing the benefits and drawbacks of these synthesis processes. Because they are environmentally safe and nontoxic, green synthesis of PtNPs are currently preferred over chemical and physical ones. This is because they can be used more effectively in biomedical applications.

Although biosynthesized/green synthesized nanomaterials exhibit high efficacy at low doses, numerous other factors, including the source of the PtNPs as a starting material, its durability, solubility, controlled release, biodistribution, concentrations, cell-specific targeting, and human toxicological issues, must also be taken into account. Additionally, multifunctional PtNPs must be loaded with phototherapeutic agents and nanocarriers for treatments and targeting in order to get around the limitations of exclusive multidrug resistance. The primary goal of molecular therapeutics is to develop novel methods that can be applied to the cellular system for early disease detection and long-term usability. The development of the theragnostic platform may be expanded to include nanoparticles, particularly PtNPs, to make the diagnostic processes simpler, quicker, and less invasive. Additionally, the quick development of new nanocomposites containing PtNPs and featuring multifunctional modalities may lead to more effective ways of utilising PtNPs as additional diagnostic medicines.

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