Green Synthesis and Zeta Potential Measurement of Silver Nanoparticles

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Abstract:

Nanotechnology has enormous potential in the fields of healthcare, right from effective drug delivering, diagnosing diseases more rapidly and sensitively, and delivering vaccines via aerosols and patches. The use of silver (Ag) nanoparticles is quite interesting both in the fields of medicine as well as in healthcare due to its various pharmacological properties. Zeta potential [ZP] can affect the pharmacokinetic properties of nano systems in the body and plays an important role in controlling the electrostatic interactions in particle dispersion. The zeta potential characterization is used to understand the nanometre size particles in the liquid.

The current study focuses on the green synthesis of metallic nanoparticles from *Ocimum tenuilforum* (Tulsi) *and Catharanthus roseus* (Periwinkle) and comparing the zeta potential values of these nanoparticles.

The zeta potential value of silver nanoparticles from Periwinkle extract showed good stability as compared to silver nanoparticles from Tulsi extract. The surface charge density of nanoparticles could be optimized further for minimal toxicity and effective intracellular delivery of encapsulated drugs.

Keywords: Nanotechnology, Silver nanoparticles, Zeta potential, *Ocimum tenuilforum* (Tulsi), *Catharanthus roseus* (Periwinkle).

INTRODUCTION:

Nanotechnology is becoming one of the foremost promising technologies applied in all areas of science. Nanoparticles have size starting from 1-100nm. The nanoscale material has new, unique, and superior physical and chemical properties compared to its bulk structure, due to an increase in the ratio of the surface area per volume of the material/particle. The most widely studied nanoparticle materials are metal nanoparticles because they are easier to synthesize. Moreover, these materials have a wide range of applications. Some of the most widely studied metallic nanoparticles are silver (Ag), gold (Au), platinum (Pt), and palladium (Pd).

Amongst the nanoparticles mentioned above the use of Ag is quite interesting especially in the field of health and medicine. Ag has a strong antibacterial activity and is known to damage bacterial cell walls, inhibit bacterial growth, disrupt cell metabolism due to its interaction with macromolecules in cells, such as proteins and DNA. The interaction of Ag ions with the cell prevents protein synthesis, decreases membrane permeability, all of which eventually leads to cell death. The silver nanoparticles (SNP) have stronger antibacterial activity due to its high reactivity as compared to their bulk form (Dugal and Shaikh, 2018).

Though there exist various ways to synthesize nanoparticles, chemical synthesis, however, is costly and requires the use of hazardous chemicals. Therefore, greener approaches, based on the use of plant extracts as well as ionizing radiation chemistry in aqueous solutions are being adopted. The biosynthesis of nanoparticles by the utilization of plants involves the use of secondary metabolites as reducing agents.

Zeta potential [ZP] is the key parameter that controls electrostatic interactions in particle dispersion and plays an important role in understanding the stability of colloidal dispersion (Huynh, et.al. 2009). Stability of nanoparticles is directly proportional to the zeta potential value. It also describes the degree of interaction between charged particles i.e the degree of repulsion between the surface charge of nanoparticles dispersed in the solvent used. Higher zeta potential values indicate high stability of nanoparticle suspension (Jabr-Milane, et.al., 2008).

Zeta potential can affect the pharmacokinetic properties of nanosystems in the body. The physicochemical properties of nanoparticles influence its biological compatibility and result in governing of nano-bio interactions (Kamaly et al., 2012). The measurement of zeta potential characterization is an important and widely used method to understand the nanometer-sized particles in the liquid. Thus, the investigation of zeta potential value gives an understanding of the heterogeneous characteristic of particle dispersion. A better nanoparticle interaction is an extremely important parameter across a wide range of industries including brewing, ceramics, pharmaceuticals, medicine, mineral processing and water treatment. The current study focuses on the green synthesis of metallic nanoparticles and compares the zeta potential values of these nanoparticles.

The ZP depends upon the composition of SNP as is considered as a function of the particle's environment. In ZP analysis there are two kinds of techniques used, Electrophoretic light scattering [ELS] and Electroacoustic determination [ED]. ELS provides better resolution and gives more reliable results than other methods. High ZP implies highly charged particles, due to electric repulsion that prevents aggregation of particles. During low ZP attraction overcomes repulsion which results in the formation of coagulates. The value of -30 m V is considered to be optimum for good stabilization of

Nano-dispersion. SNP with ZP values, between 20 mV and 40 mV, are known to stabilize the system and are less prone to form aggregate.

MATERIALS AND METHODS:

[A] Preparation of crude plant extracts:

Plants were purchased from a local nursery in Mumbai after confirmation of their identity.
Leaves of *Ocimum tenuiflorum* (Krishna Tulsi) and *Catharanthus roseus* (Periwinkle) were washed with fresh water and dried at room temperature (RT). Leaves were cut into small pieces, powdered in a mixture grinder and stored in sterile containers at 4˚C till further use. Extraction was done using Soxhlet apparatus, for which 5 grams of powdered sample and 100 ml solvent (Methanol) were used. The extract was evaporated in BWB, weighed and reconstituted in the solvent.

[B] Biological synthesis of silver nanoparticles:

To 5ml of the above prepared extracts of *Ocimum tenuiflorum* and *Catharanthus roseus* 100ml of silver nitrate solution was added (Dissolve 0.01 gram of silver nitrate in 100 ml of D/W). Presence of brownish yellow colour indicated the formation of silver nanoparticles.

[C] Characterization of Nanoparticles:

Characterization of the synthesized nanoparticles was done using an indirect measurement of the net charge on the nanoparticle (NP) surface with Zeta Potential.All measurements were carried out at temperatures of 25˚C on a Zetasizer Nano ZS (Malvern Instruments Ltd, Malvern, UK) fitted with a high-concentration zeta potential cell (ZEN1010).

Measure procedure:

The instrument was switched 30 minutes before starting the measurement in order to warm up the laser. The zeta cells were loaded as follows:

- Connect a syringe of 1 mL pre-loaded with the sample to a port of the cell.
- Orient the cell upside-down (ports oriented down) and then slowly inject the sample reaching half of the loop formed at the bottom of the cell, checking that no bubbles are formed into the cell.
- Return the cell in the vertical position (ports up) and continue to inject the sample form the syringe.
- Fill to the maximum level of the cell (total volume 0.8 mL or 0.75 mL depending on the cell).
- Then check that the electrodes are completely immersed in the liquid and there are no bubbles in the cell.
- Remove the syringe and cap the filled cells with its two caps.
- Insert the cell into the instrument according to the instruction of the manufacturer.

RESULTS:

[A] Preparation of crude plant extracts:

1] *Ocimum tenuiflorum* (Tulsi):

Weight of the beaker (A) = 187.12 g

Weight of the beaker + Solvent + Extract (B)= 190.11 g

Extract recovery (%) = Amount of the extract recovered after evaporation (g) x 100

Amount of the plant sample (g)

= 3 x 100 = 60%

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2] *Catharanthus roseus* (Periwinkle):

Weight of the beaker (A) = 109.45 g

Weight of the beaker + Solvent + Extract (B) = 114. 13 g

Extract recovery (%) = Amount of the extract recovered after evaporation (g) x 100

Amount of the plant sample (g)

= 4.68 x 100 = 93.6%

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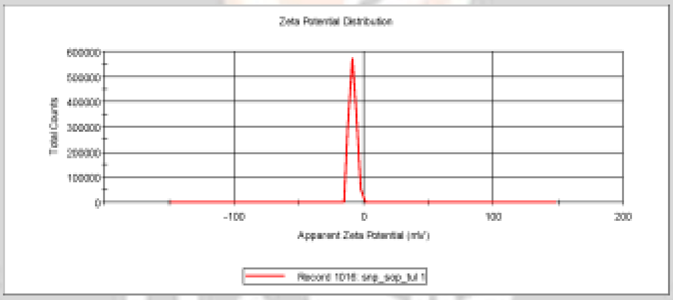

Figure 1: Zeta potential value of silver nanoparticle from *Ocimum tenuiflorum* is 8.35mV.

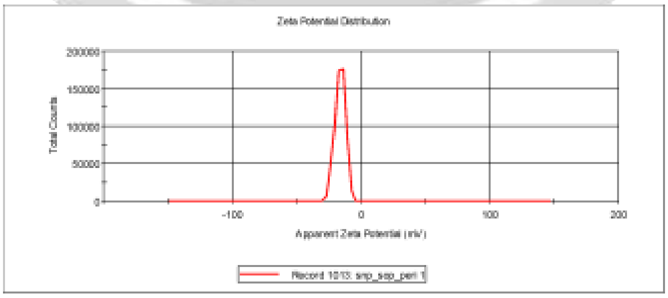

Figure 2: Zeta potential value of silver nanoparticle from *Catharanthus roseus* is -16.12mV

[B] Characterization of Nanoparticles:

The zeta potential cure versus counts captures the whole range of spectrum for silver nanoparticle from *O. tenuiflorum* (Tulsi) and *C.roseus* (Periwinkle) extract. The zeta magnitude of the zeta potential indicates the potential stability of the colloidal system. If nanoparticle suspension has large positive or negative zeta potential value, then it results in a greater tendency of repulsion. In contrast, if the particles have low zeta potential value then there will be no force for preventing the particles coming together and flocculating. So generally, stability and instability are determined between -30 mV to +30 mV (Wissing, et.al., 2004). Thus, particles with a zeta potential value between +30 mV to - 30mV show good stability.

The scientists Derjaguin, Verwey, Landau and Overbeek developed a theory (DVLO) which is related to the stability of colloidal systems which is the sum of Vander waals attractive force and electric repulsive force (Jacobs, et.al., 2000). Zeta potential value is a physical property which is exhibited by any particle suspended in liquid (Beck-Broichsitter et al., 2011). The different layers of liquid surround the dispersed particle which exists in two parts, one is an inner region (Stern layer) where the ions are strongly bound and an outer (diffuse) region where they are weekly associated. Within the diffuse layer, there is a notional boundary inside which the ions and particles form a stable entity. When a particle moves, say, due to gravity, ions within the boundary also move. Those ions beyond the boundary stay with the bulk dispersant. The potential at this boundary i.e. surface of hydrodynamic shear is the zeta potential. The magnitude of the zeta potential indicates the potential stability of the colloidal system. Conversely, a high zeta potential (either positive or negative), typically more than 30 mV, maintains a stable system (Prokop,et.al., 2002).

From figure 1 and figure 2 it is clear that the zeta potential value of silver nanoparticles from Periwinkle extract shows good stability as compared to silver nanoparticles from Tulsi extract. Nanoparticles show a high affinity for cellular membranes mainly due to electrostatic interactions (Bernfield et al., 1999).

The cell membranes which have large negatively charged domains should repel negatively charged nanoparticles. The result of the present paper shows good zeta potential value (-16.2 mV) for silver nanoparticles from Periwinkle extract as compared to Tulsi extract. Previous literature suggested that the negatively charged particles bind at the cationic sites in the form of clusters because of their repulsive interactions with the large negatively charged domains of the cell surface (Patil et al., 2007).

Colloidal stability in biological environments can be a challenging issue in the clinical application of any nanoparticle-based constructs due to the large surface area to volume aspect ratio of nanoscale materials.

CONCLUSION:

The negative zeta potential value has immense benefits. The surface charge density of nanoparticles could be optimized for minimal toxicity and effective intracellular delivery of encapsulated drugs. Thus, zeta potential value plays a vital role in the effectiveness of Nano medicine.

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