Methods Used for the Preparation of Nanoparticles in the Current Study

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Abstract - Nanoparticle medication delivery methods have received increased research funding in recent years. There are a number of benefits to using nanoparticles as opposed to more traditional drug delivery methods. Because their physical, chemical, and biological properties are so amenable to modification while still providing superior performance over bulk foils, nanoparticles have become increasingly important in technological developments. Because of their diminutive size, nanoparticles are able to freely navigate the body and access a wide variety of target organs. For this reason, nanoparticles are the optimal medication delivery technology due to their great stability and regulated drug release. In addition to these benefits, they also provide several administration options. Delivery of medications in the form of nanoparticles is possible for both hydrophilic and hydrophobic pharmaceuticals. Different types of drug molecules' pharmacokinetic and pharmacodynamic properties have been physically altered and improved through the use of nanoparticles. In comparison to other research methods, formulating metal oxides using the sol-gel method is a stress-free and very inexpensive process that allows for control over the doping process or adding of transition metals. To obtain nanoparticles with desired sizes and shapes, it is necessary to investigate various methods of synthesis. They can be used for imaging, catalysis, medical applications, and environmental uses, all of which have commercial and local potential. Nanoparticle synthesis techniques, including physical, chemical, and biological processes, are the primary emphasis of this review.

Keywords - Drug Delivery Methods, Hydrophilic and Hydrophobic pharmaceuticals, Pharmacokinetic and Pharmacodynamic Properties, Pulsed laser ablation, Sol-gel synthesis.

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INTRODUCTION

The typical size range for nanoparticles is between 1 and 100 nm. There are a wide variety of words used to describe nanoparticulate drug delivery methods. Particle dimension distribution in these drug delivery systems typically ranges from a few nanometers to a few hundred nanometers, and the carriers are typically either polymer or lipid. Attempts have been made to improve nanoparticles by using novel and inventive polymers to support their claim as drug carriers [1].

Benefits of nanoparticles

The advantages of nanoparticles over alternative drug delivery systems are summarised in table 1[2, 3].

Table 1: Advantages of nanoparticles

➢ **The improvement of bioavailability and soluble form**
➢ **Improvement in drug efficacy**
➢ **Keeping drugs in your system for a long time**
➢ **Safeguarding against deterioration**
➢ **Heightened permeability**
➢ **Fewer negative effects compared to the standard method of drug administration**
➢ **Effectiveness of treatment is enhanced.**

Nanoparticle Synthesis Influencing Factors-

- Temperature

- Pressure
- Time
- The size form of the particles
- Expenses incurred for planning

Analytical methods for synthesis

A. Top-down method

Top-down methods start with large-scale blueprints. Using these techniques, you may go from using larger particles and have them transformed into nanoparticles through a series of activities. The main drawbacks of these technologies are the substantial initial investment and the need for complex installations. These techniques are prohibitively costly and thus unsuitable for industrial-scale manufacturing. This technique can be used successfully in a controlled laboratory setting. This method relies on crushing and pulverising substances. Inapplicable to the study of soft samples, these techniques cannot be used. The steps of this procedure are depicted in a diagram in figure 1[6, 7].

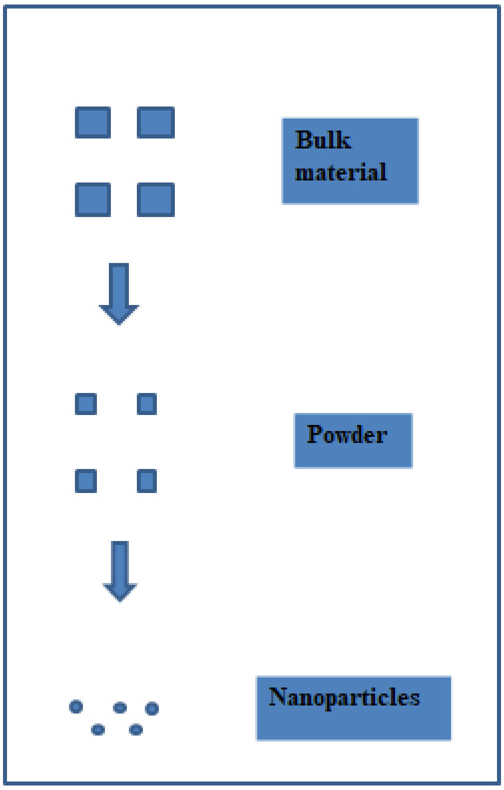

Figure 1: Top-down approach

Methods in top-down approach:

1. Physical vapour deposition
2. Chemical vapour deposition
3. Ion implantation
4. Electron beam ithography
5. X-ray lithography[8]

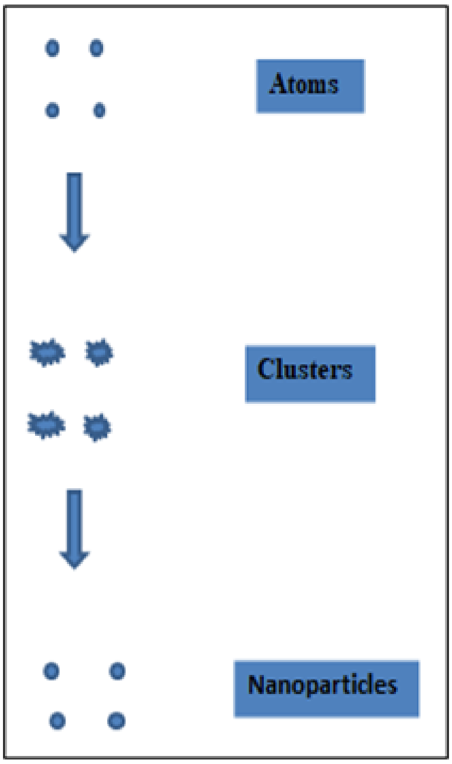

Figure 2: Bottom-up approach

B. Bottom-up approach

Nanomaterials can be created via bottom-up methods, which involve shrinking material components down to the atomic scale and then following a series of steps that ultimately result in the creation of nanostructures. Physical forces operating at the nanoscale merged simple units to form larger stable structures throughout the course of the evolution. Molecular recognition is the foundational premise for this approach (self-assembly). Growing more and more characteristics of one's type from within is an example of self-assembly. You can see a visual depiction of this strategy in fig. 2[9]

Methods in a bottom-up-approach:

1. Sol-gel synthesis
2. Colloidal precipitation
3. Hydrothermal synthesis
4. Electro deposition [11]

Methods of synthesis of nanoparticles

There are three kinds of approaches for the production of nanoparticles. These methods are listed in table 2.

1. Physical Methods
2. Chemical Methods
3. Biological Methods

Table 2: Methods of synthesis of nanoparticles

A. Physical methods

1. Mechanical Method
2. Pulse Laser Ablation
3. Pulsed Wire Discharge Method
4. Chemical Vapor Deposition
5. Laser Pyrolysis

Physical methods

1. Mechanical method

Ball milling

Innovative methods have been developed for the production of nanoparticles. Planetary, vibratory, rod, and tumbler mills are the most common types of mills in use. The container holds a number of tough balls that are likely made of carbide or steel. This method can be utilised to synthesise nanocrystalline forms of Co, Cr, W, and Ag-Fe. The number of balls to materials constitutes a ratio of 2 to 1. After being loaded with an inert gas or air, the container is then subjected to rapid rotation around its longitudinal axis. The balls and the walls of the container work together to apply pressure to the materials. When it comes to synthesising nanoparticles of the ideal size [14, 15], the speed and duration of the milling process play a significant role.

Melt mixing

Mixing molten streams of metals at high velocity with turbulence form nanoparticles. Nanoparticles get arrested in a glass. Glass–is an amorphous solid, deficient symmetric organisation of atoms or molecules. Metals, when cooled at great cooling proportions, can form amorphous solids-metallic glasses. Ex: A melted stream of Cu-B and a heated stream of Ti forms nanoparticles of TiB_2.

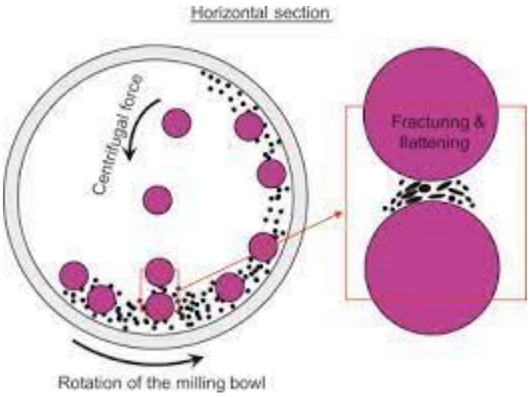

Figure 3: Ball mill

2. Pulse laser ablation

A vacuum chamber is prepared for the examination of the target sample. Plasma is generated by focusing a high-pulsed laser beam on the sample, which then undergoes a transformation that results in the formation of a colloidal solution of nanoparticles. When producing nanoparticles, the type of laser known as a second-harmonic group laser is usually utilised. The kind of laser used, the number of pulses used, the solvent used, and the amount of time spent pulsing are all factors that influence the end product.

3. Pulsed wire discharge method

The physical method for producing nanoparticles. Synthesis of metal nanoparticles by far the most common and popular method. A pulsated current is used to vaporise a metal wire, which results in the production of a vapour. This vapour is subsequently cooled by the surrounding gas, which results in the production of process nanoparticles. The potential for high fabricationspeed and great energy productivity exists within this concept. Ex. Nitride nanoparticles.

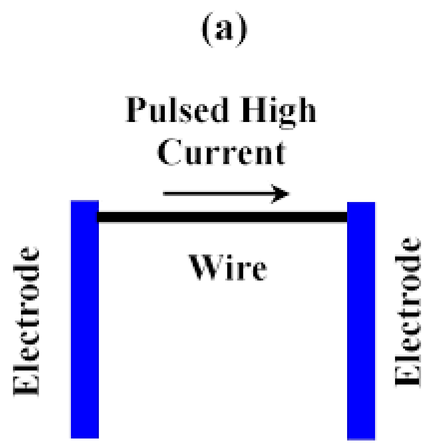

Figure 4: Pulse wire discharge method

4. Chemical vapor deposition

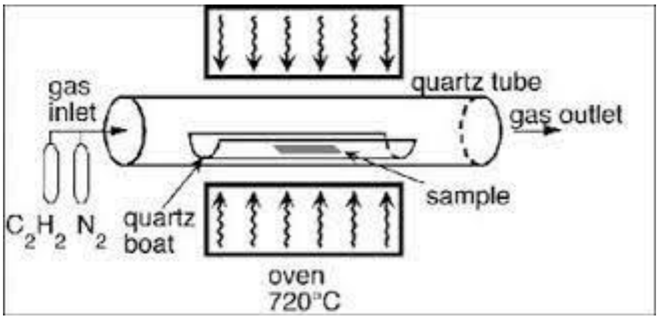

Figure 5: Chemical vapour deposition

5. Laser pyrolysis

Laser pyrolysis is the term given to the process that involves the use of a laser in order to create nanoparticles. A concentrated intense laser beam is used to decompose the mixture of reactant gases in the presence of some inactive gas such as helium or argon by focusing the laser beam. When it comes to determining the particle sizes and where they are distributed, the pressure of the gas plays a significant role.

B. Chemical methods

Sol-gel method

Condensation, hydrolysis, and thermal breakdown of metal alkoxides or metal precursors in solution are the three stages that make up this process. The result is the formation of a stable solution that is referred to as the sol. When the gel is created, either through hydrolysis or condensation, it has a higher viscosity. Changing the precursor concentration, temperature, or pH can allow the particle size to be monitored and controlled. A mature step is required in order to enable the development of solid mass. This step could take a few days and involve the elimination of the solvent, the Ostwald ripening process, and the transformation of phase. When producing nanoparticles, the unstable reagents are separated out first.

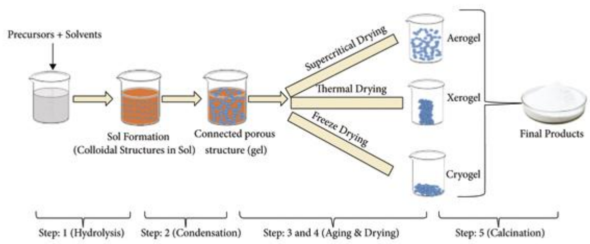

Figure 6: Sol-gel method

Sonochemical synthesis

In the presence of palladium and water, a sonochemical reaction with copper salt resulted in the formation of Pd-CuO nanohybrids. This was a successful invention. With the assistance of ultrasonic waves and the presence of palladium and water, switch metal salts are able to be transformed into their oxides. The palladium that is used can come from one of two places: either pure palladium metal Pd(0) or the palladium salts.

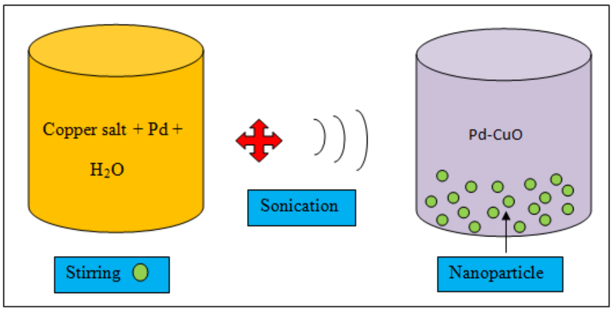

Figure 7: Sonochemical synthesis

Co-precipitation method

This procedure is a wet chemical process that is also known as a solvent displacement method. Polymer phase can be either natural or synthetic, and the solvents for polymers include ethanol, acetone, hexane, and nonsolvent polymer. After thoroughly mixing the polymer solution, the production of nanoparticles can be accomplished through the rapid diffusion of polymer-solvent into a nonsolvent polymer phase. Interfacial stress between two phases creates nanoparticles.

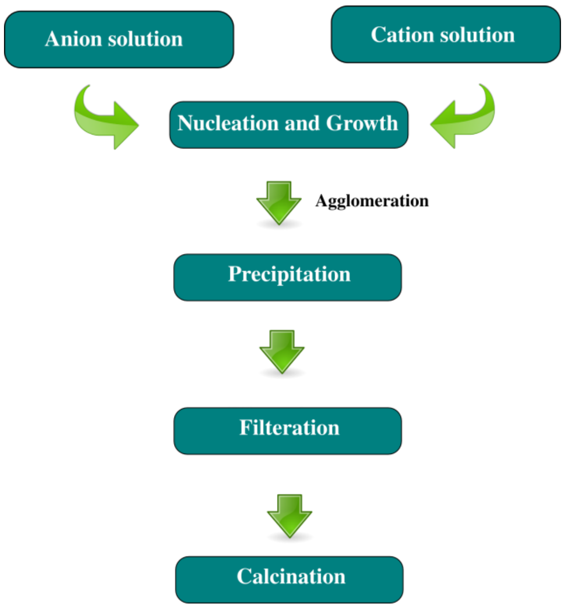

Figure 8: Co-precipitation method

Inert gas condensation method

The production of metal nanoparticles frequently makes use of this particular process. The technique of inactive gas compression, which involves the production of nanoparticles via the vanishing of a metallic source in an inactive gas, had been widely used to produce fine nanoparticles. At a temperature that can be achieved, the process of vaporising

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metals occurs at a rate that is reasonable. Copper metal nanoparticles can be manufactured by vaporising metal in the presence of argon, helium, or neon in a chamber after the metal has been placed inside the chamber. Once the atom has been boiled off, its energy is immediately lost because the vaporised atom must be cooled with an inert gas. The gases cool by liquid nitrogen, to form nanoparticles in the series of 2-100 nm .

Hydrothermal synthesis

It is one of the most usually used methods for the preparation of nanoparticles. The focus here is on a series of chemical reactions as the primary mechanism. In hydrothermal synthesis, the temperatures can range from room temperature all the way up to extremely high levels for the synthesis of nanoparticles. This method has a number of advantages that cannot be found in either the biological or the physical methods. The nanomaterials generated through hydrothermal synthesis may be unstable at higher temperature ranges.

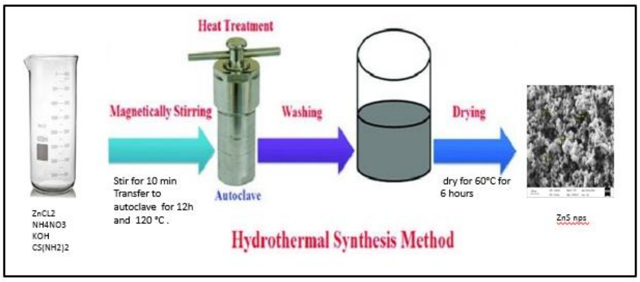

Figure 9: Hydrothermal synthesis

C. Biological methods

Synthesis using microorganisms

In recent years, there has been a rise in interest in synthesising nanoparticles by making use of microorganisms. This is primarily attributable to the fact that this method is both cost-efficient and environmentally friendly. Extracellular biosynthesis is one of the methods that can be utilised in the synthesis of nanoparticles from a microorganism. The other method is intracellular biosynthesis. Microbes of a certain kind have the ability to separate metal ions. Pseudomonas stuzeri Ag295 is frequently discovered in silver mines. This can be accomplished by collecting silver either inside or outside of the cell walls of the bacteria. Because microorganisms contain many different reductase enzyme types, they are able to both store and detoxify heavy metals. Klebsiella pneumonia can be exploited to produceCdS nanoparticles .

Synthesis with the use of plant extracts

Extracts from plants play a significant role in the biosynthesis of nanoparticles. This method is also known as a green synthesis or a green manufacturing process for nanoparticles. For the production of gold nanoparticles, the leaves of the herb known as geranium (Pelargonium graveolens) have been used. To create silver nanoparticles, 5 millilitres of plant extract has one millilitre of an aqueous solution containing one millimole of silver nitrate added to it. The same method is used for the synthesis of products derived from alcoholic extract, In the dark, the plant extract is kept in a shaker at a speed of 150 revolutions per minute, along with silver nitrate.

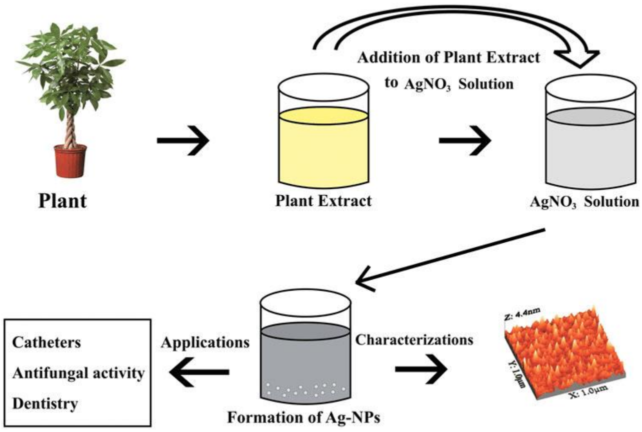

Figure 10: Synthesis using plant extract

CONCLUSION

Top-down methods can be prohibitively expensive and are generally unsuitable for use with soft samples. Though unsuitable for industrial scale production, top-down approaches can be useful in the lab. The molecular recognition principle forms the basis of the bottom-up strategy. When creating nanostructures, bottom-up approaches involve manipulating individual atoms, molecules, or clusters. Nanoparticle synthesis strategy comparisons were conducted.

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