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Nano therapeutics: A modern approach to pulmonary care

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Abstract
Every year, millions of people's health and quality of life are impacted by the rising number of respiratory disease cases worldwide. Many hospital admissions and fatalities are caused by acute respiratory infections (ARIs) and chronic respiratory disorders (CRDs), which call for advanced therapies that make the delivery of medications with regulated release to particular target sites. Various nanoparticles (NPs), including lipid, liposome, protein, carbon-based, polymeric, metallic, oxide, and magnetic NPs, have been investigated to meet this need. Because of their benefits for targeted effects, sustained drug release, and patient compliance, NPs can be used as drug delivery systems to increase the effectiveness of commercial medications. An updated synopsis of recent developments in the use of NPs as drug delivery systems to treat respiratory tract illnesses, including ARIs and CRDs, is provided in the current study. The most recent uses reported in the literature were taken into account, and the advantages and disadvantages of NPs in the field of medication administration are examined.

Keywords: Nanoparticles, COPD, respiratory mechanisms, liposome, pulmonary diseases, asthma

Introduction

Varied pharmaceutical scientists and drug regulatory organizations around the world have varied definitions for nano-formulations. The nanoscale particles made from pure active pharmaceutical ingredients (APIs) are referred to as nano formulation in this work.Using nano-formulation technology, which creates tiny particles by mixing APIswith suitable carrier materials and their final medicinal formulations. Nano-formulations end product or carrier material usually has a well-defined physical interface, substantial scaling effects, and a particle size of less than 1000 nm.

Among the main causes of death and disability worldwide are illnesses affecting the respiratory system. Over nine million deaths have been reported by the World Health Organization (WHO).

were linked to respiratory illnesses in 2016, which accounted for 15% of all fatalities globally. Lower respiratory infections, lung cancer, TB, and chronic obstructive pulmonary disease (COPD) are among the top 10 causes of death worldwide. Since the respiratory system's organs are so susceptible to airborne illnesses and damage, the health sector must prioritize protecting them. A growing number of pathologic entities in the aging population include respiratory disorders. The evolving lifestyle of our society and the high aspirations for a higher quality of life necessitate better, more economical and effective medical care.

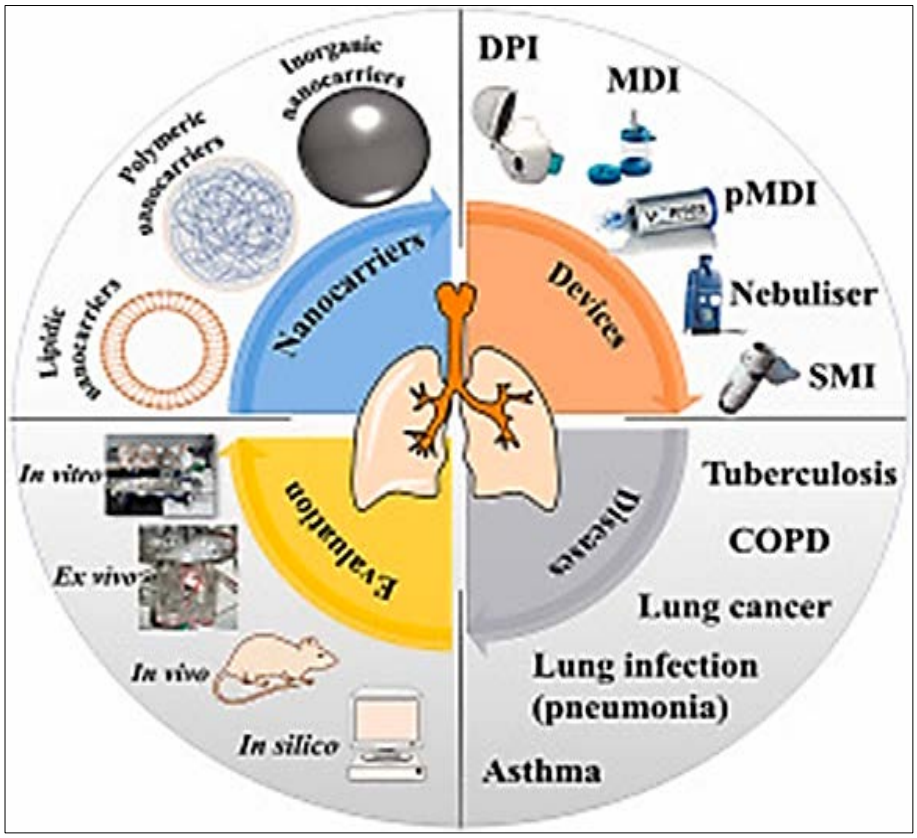
Historically, the lung has been used to treat a wide range of pulmonary conditions, including lung cancer, chronic obstructive pulmonary diseases (COPD), idiopathic pulmonary fibrosis (IPE), pneumonia, cystic fibrosis, asthma, and infections such as pulmonary tuberculosis(TB), Some of these conditions are crippling and occasionally fatal, and there are currently no effective treatments to restore lung function.

All around the world, respiratory injuries result in disabilities and fatalities; nevertheless, substandard living circumstances, including overcrowding, poverty, exposure to pollution, and a lack of appropriate. The prevalence and susceptibility of respiratory-related illnesses are increased by an adequate health system.

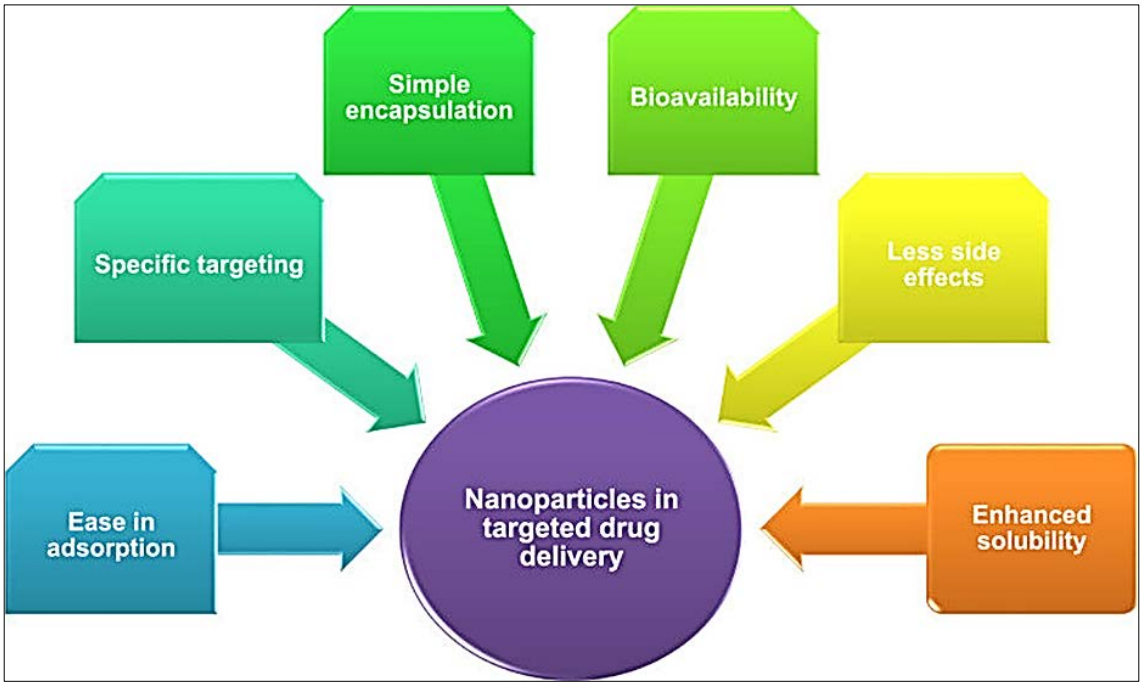
Furthermore, having respiratory conditions causes a great deal of hardship, particularly for the most underprivileged groups. The first and least expensive way to lessen the incidence of respiratory disorders is through preventive measures. Avoiding exposure to polluted air, such as tobacco smoke and air pollution, can help prevent respiratory disorders.

The possibility of using nanoparticles as effective medication delivery vehicles to target particular cell populations in the respiratory system is constantly being researched. Therefore, inhalation of nanoparticles could be crucial in the near future for the treatment of individuals suffering from lung conditions like asthma, COPD, cystic fibrosis, and chronic pulmonary infections like tuberculosis [2-5].

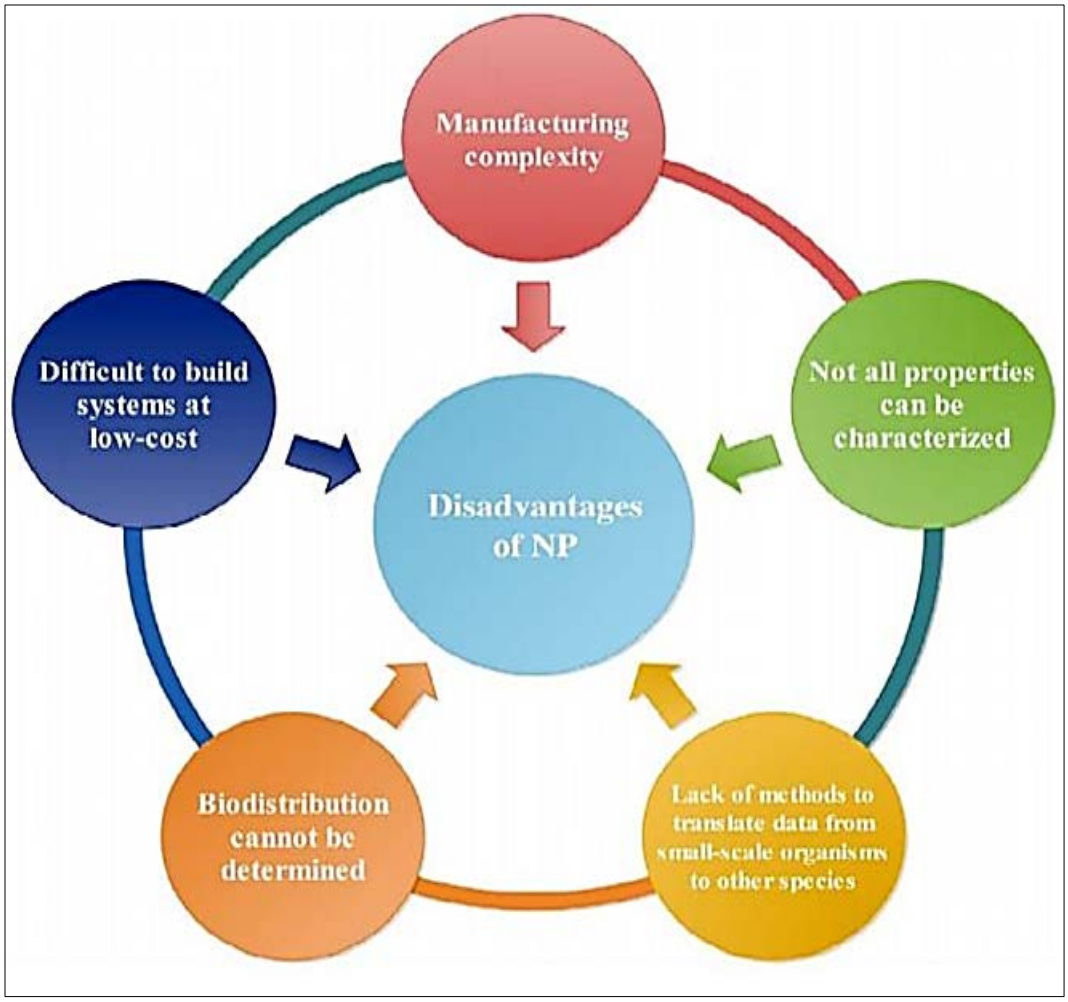
Advantages



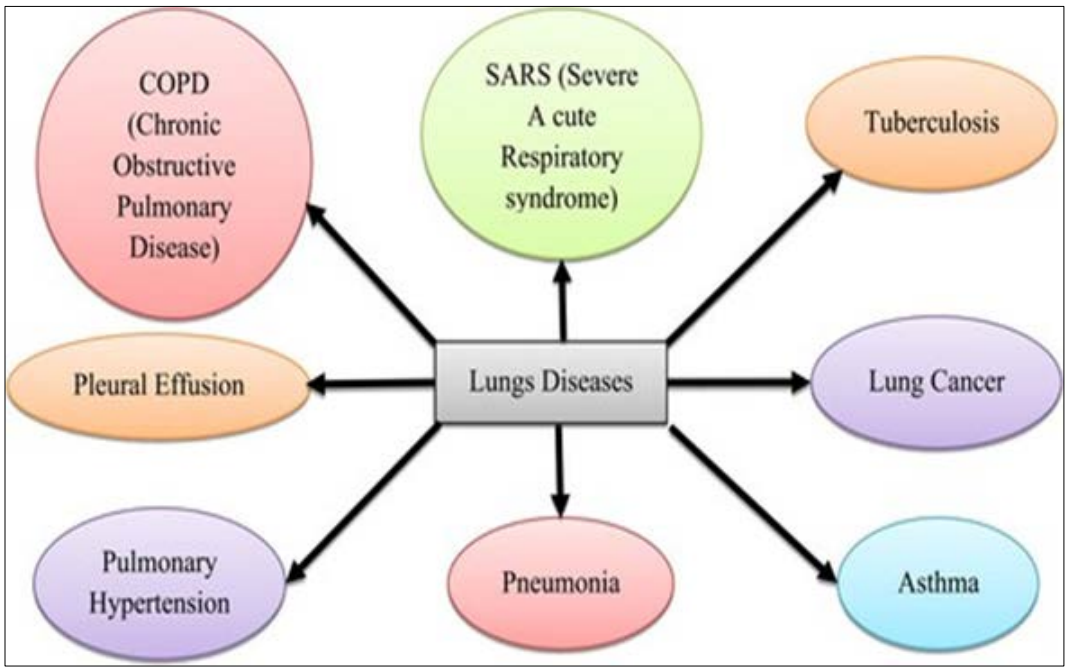
Disadvantages



Brief description about lung diseases



COPD (Chronic obstructive pulmonary diseases)



- **COPD (Chronic obstructive pulmonary diseases)**
  cOPD as defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2023 report, is a heterogeneous lung disease characterized by persistent, often progressive airflow obstruction brought on by abnormalities of the alveoli (emphysema) and /or airways (bronchitis, bronchiolitis). These anomalies result in persistent respiratory symptoms, including

coughing, expectoration, exacerbations, and dyspnea. COPD ranks among the top three causes of death worldwide, with a stunning 90% of these deaths occurring in low and middle-income countries (LMIC), according to the GOLD 2023 report [7].

- **Asthma**
  The term asthma refers to a chronic inflammatory illness of the airways. The airways with this syndrome are hyperresponsive because of specific stimuli, including particular illnesses, allergies, and physical exercise. Chest tightness, wheezing, dyspnea, and/or cough-like symptoms are recurrent episodes brought on by chronic inflammation. Episodes of symptoms are frequently caused by a large, but varied, restriction of air in the lungs. An effective antiasthmatic drug, such as a fast-acting bronchodilator, can help reverse this obstruction or it can be reversed naturally. Numerous drugs such as oral and inhaled corticosteroids, β2-agonists (short or long acting), leukotriene receptor antagonists, leukotriene synthesis inhibitors, and muscarinic antagonists (short or long acting) in different dosage are used to treat asthma [7].
- **Pneumonia**
  The germs that cause a pneumonia infection generate a lot of secretions and mucus. The presence of fluid in air sacs hinders gas exchanges between O2 and CO2, causing O2 to decrease and CO2 to increase. Legionella pneumoniae. After Complement C3b is placed on the alveolar surface, it enters alveolar macrophages and attaches to the surface of the macrophages utilizing the host's protein as a ligand, which allows pneumonia to enter. Even when bacteria reside inside vacuoles, they do not combine with lysosomes to remain there. Streptococcus pneumonia's polysaccharide capsules serve as an anti-phagocytic agent to increase the bacteria's longevity within macrophages [7].
- **Lung Cancer**
  Exposure to respiratory toxicants increases the risk of lung cancer, which has long been and continues to be the major cause of cancer-related death. Both men and women who smoke have a 25-fold higher risk of dying from lung cancer than nonsmokers and CS accounts for a sizable portion of lung cancer fatalities. Lung cancer arises when cells are harmed by prolonged exposure to respiratory pollutants, which then interferes with DNA repair and cell cycle control. Inflammation caused by respiratory toxicants exacerbates this effect. In addition to uncontrolled cell proliferation, neo angiogenesis and tissue remodeling also affect tumor progression [6].
- **Tuberculosis**
  Mycobacterium tuberculosis is the causative agent of tuberculosis (TB), an infectious bacterial disease that primarily affects the lungs but can also affect the kidneys, spine, and brain. TB can be either an active disease or a latent (inactive) infection that is spread through the air when an infected person coughs, sneezes, or sings. Even though tuberculosis is preventable and treatable, it is still one of the leading causes of infectious deaths globally and must be treated with a lengthy course of antibiotics to avoid major health effects [12].
- **Pulmonary Hypertension**
  High blood pressure in the arteries that provide blood to the lungs causes pulmonary hypertension (PH), which manifests as symptoms like exhaustion, shortness of breath, chest pain, and edema. Although the condition may have unknown roots (primary PH) or be caused by other underlying disorders (secondary PH), it is a serious condition that can result in right-sided heart failure and may not be cured, however therapies help manage symptoms and avoid damage. It is categorized into five World Health Organization (WHO) groups according to its particular etiology and features and diagnosis includes tests such as echocardiography and cardiac catheterization [18].
- **Pleural Effusion**
  The abnormal accumulation of extra fluid in the pleural space, which is the space between the lungs and the chest wall, is known as a pleural effusion or fluid on the lung. This accumulation, which is brought on by underlying illnesses including heart failure, pneumonia, cancer, or kidney disease, can manifest as symptoms like coughing, chest pain, and shortness of breath. Draining the fluid may be part of the treatment, which aims to address the underlying problem [13].
- **SARS (Severe acute respiratory syndrome)**
  A respiratory disease brought on by a corona virus that is infectious and occasionally lethal.
  In China, SARS first surfaced in 2002. Although it was swiftly restrained, it spread around the world in a matter of months. When a person with SARS coughs, sneezes, or speaks, the virus spreads by airborne droplets. With the COVID-19 pandemic in 2019, it made a comeback. Symptoms include fever, headache, muscle pains, dry cough, and dyspnea. Supportive care is the only available treatment [14].

Respiratory Mechanism

The exchange of gases between the body and the outside world, mainly carbon dioxide and oxygen, is handled by the respiratory system. Cellular respiration, the process by which cells consume oxygen to produce energy, depends on this mechanism, which combines mechanical and metabolic elements. The pleural cavity's positive and/or negative pressure actively inflates the lungs, which resemble inflating balloons. Negative pleural pressure (Ppl) is adequate to expand the lungs during the inspiratory phase of normal breathing. To comprehend how breathing occurs, one must grasp the pressure of expansion.

The formula for inflation pressure, also known as transpulmonary pressure (Ptp)

$$Ptp = Paw - Ppl,$$

Were

Ptp stands for transpulmonary pressure, Paw for alveolar pressure, and Ppl for pleural pressure [8].

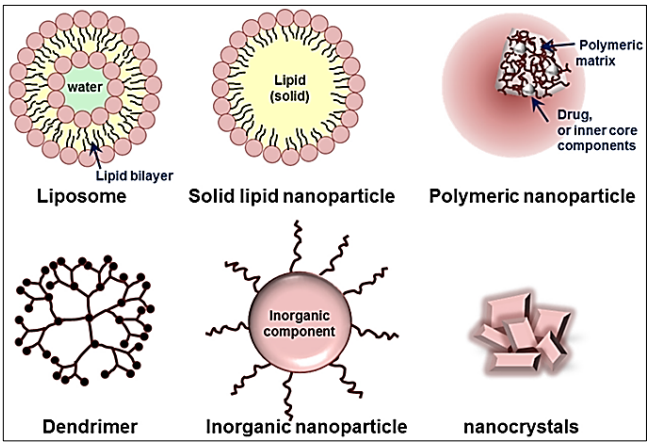
Factors regulating nanoparticles

- **Techniques for synthesis:** Different inhalable nano-formulations can be synthesized using a variety of techniques, which can be broadly divided into top-down and bottom-up approaches. The breakdown of bigger solids is referred to as "top-down methods." particles into smaller nanoparticles using outside processes such wet milling and high-pressure homogenization. Bottom-up techniques are those that create nanoparticles at the molecular level by precipitation, crystallization, and

solvent extraction using techniques including extrusion, solvent evaporation, and ant solvents [4].

- **Clarification of structure**: We must ascertain the nanoarchitectonics, which includes the atomic, molecular, nanoscale, and mesoscale structures, for manufactured nano-formulations. Methods like the infrared and ultraviolet spectrums, nuclear
  It is possible to use X-ray diffraction, mass spectrometry, magnetic resonance spectroscopy, and X-ray photoelectron spectroscopy [4].
- **Particle size in aerosols:** The pharmaceutical industry has tried to create homogenous aerosol compositions using monodispersed particles. In spite of the efforts, the aerosols typically show a broad range of
  of particle size distribution while simultaneously influencing the particles form.
  As previously stated, variations in particle size and shape could result in accumulation of these particles in a number of undesirable respiratory tract areas.
  Therefore, obtaining a monodisperse aerosol is crucial. Monodispersed particles in a perfect aerosol system are thought to have a geometric standard.
  GSD (standard deviation) of 1. However, in reality, aerosols with a GSD of less than 1.22 are regarded as tolerably monodisperse, and any system with a higher GSD is either polydispersed or heterodispersed, due to the challenges in creating perfect aerosols. Therefore, achieving a monodisperse aerosol system with a GSD of less than 1.22 should be the goal of the manufacturer and researchers [9].
- **Particle density and shape:** The aerosolization and deposition mechanisms are significantly influenced by the particle's density and shape.
  As previously said, the particles' deposition method depends
  on the particles' aerodynamic diameter. The density and shape factor of the individual particles are taken into account when calculating aerodynamic particles, making them important considerations. Different shaped particles produce varying terminal settling velocities and drag forces, which alter the aerodynamic diameter, which is again connected to the deposition mechanism. It has been discovered that an increase in surface roughness due to particle shape change reduces the aerodynamic width, allowing the particles to enter deeper lung regions as compared to that
  of globular constituents. Additionally, it has been shown that longer-lived particles have a propensity to linger in the atmosphere, allowing them to reach deeper regions. In contrast extremely lengthy particles also encounter deposition based on interception interparticulate interactions are another phenomenon that is influenced by particle shape. Vander Waals force underlies these interactions, and as a result, the particle from that permits reduced exposure area will result in fewer interactions between particles, which will stop particle aggregation and enhance aerosolization efficiency. Higher attraction forces made elongated particles unsuitable for aerosolization [9].
- **Drug-transporting ability:** When compared to formulations, the huge specific surface area or accommodation room of nanoparticles enables surface adsorption or physical encapsulation of drug molecules, improving the drug's carrying capacity.
  With more substantial particles.The ability of nano-formulations to transport drugs is typically assessed using High-Performance Liquid Chromatography (HPLC) or HPLC tandem techniques [4].
- **Release actions:** After being deposited in the lungs, inhalable nano-formulations are often anticipated to provide a quick and comprehensive release profile, enhancing bioavailability. The behavior of nano-formulation's release is frequently Sinvestigated *in vitro* by mimicking the *in vivo* environment (such as stimulating lung fluid) [4].
- **Physical stability**: The physical stability of aerosol suspensions is one of the crucial elements that need consideration. The aerosols typically contain extremely high particle concentrations in a tiny volume, which causes a number of
  interactions between particles, such as aggregation and repulsion. These interactions may cause particle aggregation and suspension instability under various storage settings, which would affect how well the product works when inhaled. For particles produced by devices like dry powder inhalers, where spray drying is the standard technique, this element is very crucial.A large number of spray-dried chemicals are amorphous, and these, prone to acquire moisture and show an increase in aerodynamic diameter when kept in high humidity conditions. Because of the increased capillary tensions between the particles, this moisture gain causes the aerosolization to degrade. Excipients such mannitol, trehalose, and lactose are therefore added to the aerosol formulations to prevent this type of instability and preserve long-term physical stability while enhancingaerosolization efficiency [9].
- **Hazardousness:** The two main causes of nano-formulation toxicity are nanocarriers and APIs. The toxicity of nanocarriers is key in the field of pharmaceutics. Due to their difficulty in being phagocytosed by macrophages, smaller nanocarriers are kept in the alveoli, potentially causing negative outcomes. Moreover, the formulations leftover metal ions and organic solvents may result in inflammatory and other negative effects. To evaluate the nano-formulations' safety, we must perform toxicity tests both *in vitro* and *in vivo*. Interestingly, it is noted that local toxicity can be reduced by precisely targeting the nano-formulations to avoid non-specific interactions with lung cells [4].

Nanoparticle variants for Pulmonary Disease Therapy



- **Liposome**
  Since the early days of nanobiotechnology, lipid-based materials, such as cholesterol and phosphatidylcholine, have been utilized to create nanoparticles because they are biocompatible. Although the structures of liposomes and solid lipid nanoparticles differ somewhat. Large doses of pharmaceuticals can be transported using lipid-based nanoparticles, and their exterior lipid layers facilitate simple cellular uptake. Because liposomes and solid lipid nanoparticles are often stable during aerosolization for inhalation, they are very beneficial for chronic lung disorders. Considering these many advantages, Over the years, lipid-based nanoparticles have been investigated as a possible drug delivery mechanism for the lungs. Chronic lung disorders have recently been treated with nanoparticles containing antioxidants, anticancer medications, antibiotics, and antiasthma medicines [7].
- **Dendrimers**
  Dendrimers are molecules with many branches that have better physicochemical characteristics than ordinary macromolecules. Dendrimers are often quite monodispersed nanoparticles, and the finished formulation's size and surface functionality can be accurately controlled. Numerous medications can be carried by dendrimers, and the PEG-modified dendrimer exhibits good pulmonary absorption following inhalation. Therefore, dendrimers have been widely employed to deliver therapies for chronic lung disorders; it has been demonstrated that dendrimers can transfer steroids, antibiotics, and anticancer drugs to the lungs [7].
- **Lipid nanoparticles in solid form**
  Colloidal lipidic nanocarriers known as solid-lipid nanoparticles (SLN) have a solid core made of physiological lipids that naturally break down and are stabilized by surfactants. Their sizes vary from 40 to 1000 nm. The micro-emulsion technique and high-pressure homogenization are the two main ways to obtain SLNs. As an alternative to traditional nanocarrier systems for pulmonary distribution, solid-lipid nanoparticles have just lately been produced. Due to its significant medication absorption and extended physical stability when compared to liposomes. Furthermore, their toxicity profile is believed to be less hazardous than that of polymeric nanoparticles due to the fact that, among other things, their production procedures need a very small amount of organic solvent and that their core is made up of physiological lipids, which have lower cytotoxicity and higher tolerance [1].
- Inorganic nanoparticles Gold, iron oxide, and silica are examples of inorganic materials that have been utilized to create nanoparticles. Because of their distinct magnetic and plasmonic characteristics, inorganic materials (such as gold and iron oxide) produce contrast for imaging using positron emission tomography (PET), magnetic resonance imaging (MR), or computed tomography (CT). As a result, inorganic nanoparticle platforms are also employed in disease diagnostic imaging. Because cationic metal ions readily bond to anionic DNA and RNA molecules, metal nanoparticles especially gold nanoparticles have been thoroughly investigated for gene transfer. Despite these benefits, inorganic nanoparticles have only had patchy results when used to treat long-term pulmonary conditions. In a mouse model of COPD, gold nanoparticles were successfully introduced into the alveolar epithelial cells but a significant amount of the nanoparticle's toxicity is still a big worry. Additionally, when intravenously injected, positively charged gold nanoparticles may bind to negatively charged serum proteins to create aggregates. According to a recent study, PEG surface modification of gold nanoparticles can stop them from aggregating. However, long-term research and therapeutic applications of gold nanoparticles are still hampered by their poor excretion. Furthermore, inorganic nanoparticles cannot transport chemical drugs in significant quantities. Consequently, these restrictions must to be thoroughly addressed before the clinical trials of inorganic nanoparticles [1].
- **Nanocrystals**
  For pulmonary drug delivery, pure drug particles reduced to the nanoscale known as nanocrystals—are utilized to increase the solubility and bioavailability of poorly soluble medications. Improved aerosolization, controlled drug release, targeted distribution to deeper lung areas, and the capacity to get past physiological obstacles such mucociliary clearance are some advantages of this carrier-free technique. The design of efficient inhaler devices for their distribution, comprehension of toxicity and clearance mechanisms, and control of particle size and stability are obstacles, though [15].
- **Polymeric nanoparticle**
  Using polymeric nanoparticles to focus medications to the lung, shield them from deterioration, and provide controlled release enhances therapeutic efficacy in pulmonary drug delivery. Because these nanoparticles are inhaled and composed of biocompatible materials including PLGA, chitosan, and gelatin, they have a lower systemic toxicity and more localized pharmacological activity. The capacity to transport a variety of cargo, such as proteins, peptides, and genetic material, as well as higher local drug concentrations and improved drug penetration into lung tissues, are important benefits [16].

Device for delivering drugs

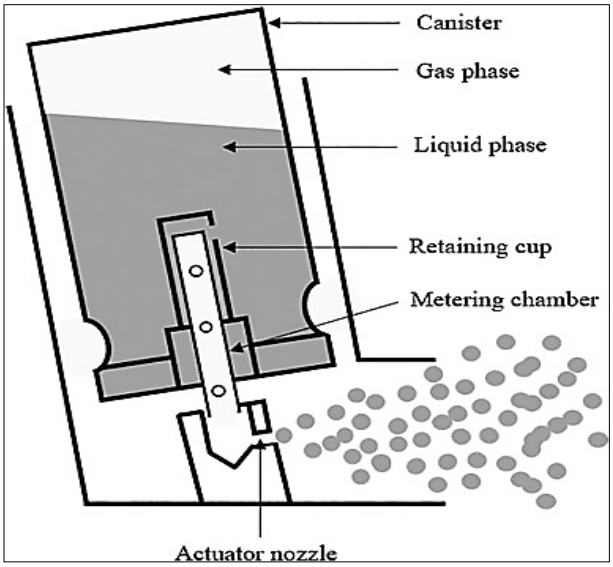
The three primary devices for pulmonary medicine delivery are nebulizers, dry powder inhalers, and metered dose inhalers.

- **Nebulizers**
  Nebulizers are among the oldest inhalation devices. These create 1-5 μm droplets from liquid compositions. Using a nebulizer has the advantage of removing the need for patient coordination between activation and inhalation, which is convenient for elderly, pediatric, and ventilated patients. Furthermore, compared to conventional breathing equipment, these are able to provide larger quantities of medication. Nebulizers can also be classified as jet nebulizers, mesh nebulizers, or ultrasonic nebulizers. Jet nebulizers, also referred to as "pneumatic nebulizers," work on the Bernoulli principle to create aerosols. Facemasks, mouthpieces, nebulizer chambers, and compressors are the primary structural components of jet nebulizers. These can be used to nebulize any type of liquid, solution, suspension, or oil. In contrast, ultrasonic nebulizers use high-frequency (1-

3 MHz) vibrations of piezoelectric crystals to create aerosol. These do not nebulize high-viscosity liquids. There aren't many trials showing this device's effectiveness in patients on mechanical ventilation, despite the fact that it might be useful in weaning patients with COPD off of ventilators.

There are two types of nebulizers available on the market:

- **Jet Nebulizers:** Using compressed gases, these devices, which are commonly employed in clinical settings, produce aerosol droplets within the respiratory range.
- **Ultrasonic Nebulizers:** These machines use ultrasonic energy to turn liquid into aerosols.
  Nebulizers could be a good alternative to inhalers for those with asthma and COPD who are unable or reluctant to use inhaler devices. More current formulations might offer a relevant development for better nebulization of medications [7].
- **Dry Powder Inhalers**
  Another type of pulmonary delivery device that requires less coordination between breathing and actuation to deliver powdered medications to respiratory tracts is the dry powdered inhaler (DPI). DPIs are more chemical stability since they contain the drugs in a dry state rather than suspensions or solutions, as is the case with pMDIs. It is difficult to formulate and produce dried powder particles with the right properties for aerosolization and pulmonary delivery, but. Typically, the dry powder is made up of big excipients including lactose, sucrose, and glucose along with micronized medication particles. There are several types of DPIs available, including numerous reservoirs, single-unit doses, and multiunit doses. The patient' sinspiratory attempts provide the DPIs with the energy they need to deliver drugs, the spiral chamber, manifold, mesh, and cyclone are structural elements of DPIs. These elements need to be able to use the force of inhaling to break apart the drug excipient complexes. Although the minimum inspiratory power needed varies depending on the product, 30 to 60 L/min is advised [9].
- **Metered Dose Inhalers**
  A transitory, cavitation turbulent fluid that flies into quickly evaporating droplets is a component of MDI mechanics. MDIs are still a common aerosolized delivery method that, when used with HFA propellants, can create aerodynamic particles smaller than 5 microns. HFA-powered MDIs are multidose, tamper-proof, and portable.
  They provide a straightforward and affordable method with precise liquid actuation by volume while shielding the remaining product from oxidation, light, and moisture. The MDI mouthpiece releases the aerosol medication dose in a quickly moving cloud of big droplets. Nevertheless, the droplet diameter at around the rear of the neck distance
  is decreased as a result of propellant evaporation, and a suitably proportional amount of the "polydispersed" aerosol cloud is now sufficiently small to enter the lung. Because to inertial impaction of the "ballistic portion" of the spray, a portion of each "metered dose" is lost in the actuator mouthpiece and another amount is lost in the oropharynx. Shown in the below fig [10].



Pharmaceutical application

When it comes to pulmonary medication administration, nanoparticles are utilized to get past lung barriers, increase drug stability and solubility, and give prolonged release, all of which lower dosage frequency and improve patient compliance. By adjusting the size, shape, and surface characteristics of nanoparticles (such as liposomes, polymeric nanoparticles, and chitosan-based carriers), they can be directed to particular lung tissues for systemic insulin delivery or local treatment of respiratory conditions like asthma and COPD, all while reducing side effects. Moreover, nanoparticles improve the bioavailability of poorly soluble medications and improve drug uptake by cells, showing great promise in the treatment of genetic abnormalities, lung malignancies, and respiratory infections. [17].

- **Managing Respiratory Conditions:** Anti-inflammatory medications are delivered via nanoparticles to treat ailments including COPD and asthma.
- **Fighting Infections:** They are employed to administer antibiotics and antimicrobial medicines to treat lung infections caused by bacteria, viruses and tuberculosis.
- **Treatment for Lung Cancer:** By delivering chemotherapeutic medications straight to lung cancers, nanoparticles can lower systemic toxicity and increase drug concentration at the spot.
- **Systemic Drug Delivery:** Drugs such as insulin can be administered systemically through the lungs in a non-invasive manner and prolonged release from nanoparticles improves patient adherence and lowers the frequency of doses.
- **Gene therapy:** This may be used to treat hereditary diseases like cystic fibrosis by introducing genetic material such as DNA or RNA into lung cells [17].

Future Perspectives

Solid-state inhalable nanoparticles as inhalable powders for targeted pulmonary delivery have special benefits and represent a novel field of study. But there are restrictions. Hazardousness
is essential for creating safe dry powder inhalation formulations. This comprises the study of nanoparticles, polymers, and other excipients. Recent studies have focused on nasal delivery of inhalable nanoparticulate powders,

especially for non-invasive brain targeting, systemic medication delivery for pain management and vaccination applications. Nanoparticle stability, dispersion, and deep lung deposition can all be enhanced by surface modification and formulation adjustment. Numerous techniques for processing pharmaceuticals can be used, such as milling, supercritical fluid extraction, condensation aerosol growth, thermal condensation, advanced spray drying, spray freeze drying, and PRINT technology [11].

Conclusion

An overview of the many NPs employed in medication delivery for the treatment of respiratory diseases is provided in this article. The number of CRDs and ARIs has grown over time, posing a serious threat to health and the quality of life. Therefore, one of the top goals for the global health industry must be the cure of chronic diseases. Thus, because of their direct targeting impact and controlled release of medicines, organic and inorganic NPs have proven to be a great substitute for improving drug distribution. Modern medications can be combined with the latest technology NPs to create new systems with improved treatment efficacy and fewer side effects. Novel research revealed that the organic NPs had a great deal of promise for treating lung cancer, TB, ALI, ARDS, asthma, CF, and COPD. Furthermore, Lung cancer, TB, and influenza have all been successfully treated using inorganic NPs. Even though employing NPs as drug carriers resulted in sustained drug release, several issues need to be fixed to make the move from labs to clinics easier. The toxicity of these substances to the human body is one of the current biological hurdles. Adverse effects of drugs. A further obstacle pertains to the paucity of published research on the subject, particularly with regard to *in vivo* study. With a thorough analysis of their behavior in long-term therapy and in-depth research on the actual impacts in human beings, a more accurate assessment of these new technological systems will be achievable. To ensure that the treatment is safe for the patients and can fulfill the aspirations of a healthy life, more research is still needed to maximize the targeting effect, controlled release, and medication efficacy. To sum up, the research mentioned in this review demonstrated that both organic and inorganic nanoparticles are essential for creating multipurpose drug delivery systems that have better health outcomes than traditional ones.

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