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Original Article

Nanomaterials for Environment Remediation

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Abstract

In today's digital era, social media has emerged as a pivotal force shaping modern consumer behaviour, fundamentally altering the landscape of consumption trends and the decision-making processes that accompany purchasing. This study embarks on an in-depth exploration of vital elements, such as peer recommendations, influencer marketing, brand interaction, and user-generated content. Together, these factors illuminate the intricate ways in which various social media platforms influence consumers' buying choices.By meticulously dissecting these components, we strive to uncover the complex dynamics that govern how social media sways purchasing decisions, thereby revealing wider implications for businesses navigating this digital terrain. Our investigation delves into the behavioural and psychological intricacies of online consumer decision making, scrutinizing the powerful effects of digital word-of-mouth, the phenomenon of social proof, and the crucial role of trust in shaping customer choices. Furthermore, this study casts a wide net over diverse demographics engaging with social media content, casting light on how targeted advertising and personalized recommendations reverberate through purchasing behaviours. Utilizing a blend of qualitative and quantitative research methods, we aim to capture the evolving tapestry of consumer buying habits in this fast-paced digital age.The insights gleaned from this research are set to empower businesses with a deeper understanding of the profound effects of social media on consumer psychology. This knowledge will enable them to refine and enhance their marketing strategies, foster greater engagement, and drive improved conversion rates.

Keywords: *Social Media, Consumer Behaviour, Purchasing Patterns, Influencer Marketing, Brand Engagement, Digital Marketing, Social Proof, User-Generated Content, Online Advertising, Consumer Decision-Making.*

Introduction

Nanotechnology involves the development of cleanser and greener technology that has various health and environmental advantages. Nanomaterials have recently been used for water and soil contamination in India. It has been developed at various locations such as Bengaluru, Tata Chemicals, and other research areas. Nanotechnology plays an important role in the environment by reducing the energy mechanism for manufacturing and production processes; as a result, it helps reduce uptake during manufacturing and production processes. Hence, this will help in the development of eco-friendly materials. Various types of pollutants, such as dyes, heavy metals, and pesticides, cause damage to the environment. Many other types of nanomaterials are used to treat pollutants, such as *Chemical Method, Physical Method, Biological Method*. Effects of pollutants on human health. It causes various diseases, such as Asthma, Cancers, Heart disease, CNS dysfunction, and skin disorders. Nanotechnology serves as a remedial option to overcome such effects on living organisms and the environment. The effectiveness of physical methods (plasma method) and chemical methods (gas phase and lithography) for the remediation of some pollutants in the environment. Some pollutants are not easily remediated by both methods, but are more effectively remediated by biological methods (green synthesis). The rapid increase in pollution can be controlled by green synthesis. Green synthesis does not involve any toxic solvents or byproducts ideal for environmental applications.

Review of Literature

Nanomaterials have significant potential for addressing various environmental issues

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including water purification, air pollution control, and soil remediation.Nanomaterials possess unique physiochemical properties, such as high surface area, reactivity, and tunable surface functionalities, which are ideal for capturing, degrading, or transforming pollutants. Various types of nanomaterials such as Metal and Metal oxide nanoparticles are used to degrade organic and inorganic pollutants and heavy metals. Carbon-based nanomaterials are widely used for the adsorption of contaminants because of their large surface area and chemical stability. Zero- valent metals are effective and can be used to reduce dichlorination and heavy-metal detoxification. Nanomaterials applied for environmental remediation help in water treatment, especially for the removal of dyes, heavy metals, and pathogens through adsorption. Air purification is carried out using titanium dioxide and nanomaterials, which helps to produce volatile organic compounds. Soil remediation using bio-nanomaterials helps degrade pollutants in contaminated soils. Nanomaterials exhibit high efficiency and specificity, enhanced degradation kinetics, and potential for regeneration and reuse. Nanomaterials are eco-friendly and biodegradable. The remediation of environment is possible by nanomaterials especially the "Green synthesis" also called biological synthesis technique is most effective in future due to increase in pollution in environment. Green synthesis can help reduce the threat of environmental pollution. To support nanomaterial synthesis, green synthesis is more effective than physical and chemical methods for the synthesis of nanoparticles because physical and chemical methods have some impact on the environment. Hence, Green synthesis and its effectiveness help conserve the natural diversity of the environment without any consequences.

The concept of using nanomaterials for environmental remediation was introduced from 1990 to 2000, although nanoscience itself has roots going much faster. The concept of green synthesis is. Biological Synthesis of nanoparticles has been used to reduce concerns over toxicity by using plant extracts and microbes. Nanomaterials have helped increase interdisciplinary research combining nanotechnology with biotechnology and environmental engineering.

Research Hypothesis:

Nanomaterials possess enhanced surface reactivity and high surface area, which will significantly improve the efficiency and selectivity of environmental remediation processes compared to conventional materials. Remediation of the environment is performed through physical, chemical, and biological methods of nanomaterial synthesis.
This explains the strength of nanomaterials with precise levels for various pollutants for remediation through physical, chemical, and biological methods. This will help avoid the effects of pollutants on living organisms and the environment.

Methodology

Different methods have been used to synthesize nanoparticles. Different impact methods on the environment are given. This helps explain the mechanism of nanoparticle formation and impact of remediation on the environment. All physical, chemical, and biological methods (green synthesis) help to understand nanomaterial synthesis and the direction of the mechanism. The detailed impact and future advantages of nanoparticles and their effectiveness in the future are preferable for controlling environmental pollution.

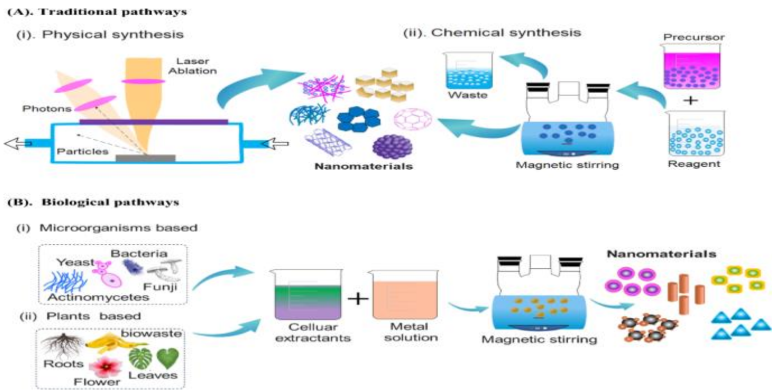

***Fig :** Physical pathway , Chemical pathway & Biological pathway*

The chemical Method was secured using *polyols* for synthesis. Because polyols act as solvents and reducing agents, they also have the ability to facilitate the nucleation and growth of nanoparticles. It possesses a high boiling point of up to 32 °C. Instead of *Polyols,* several other chemicals are used, such as *Sol-gel, hydrothermal synthesis, microemulsion* by reducing agents, which can help synthesize nanoparticles. Various organic and inorganic reducing agents can be used to reduce metal ions to nanoparticles, such as sodium citrate, ascorbate, and sodium borohydride. The simplest method that can be used for nanoparticles is by using light or electrons to create patterns on a substrate that can be used to fabricate nanoparticles *(lithography)*. Abundant air pollution can be avoided by *Gas phase synthesis* which involves the synthesis of nanoparticles using gas phases such as chemical vapor deposition. *Gas phase synthesis can be mechanized* by 1) precursor generation, which helps generate gaseous precursors that can be achieved by methods such as evaporation, sputtering, and Chemical Vapor Deposition (CVD). 2) Condensation and Nucleation – The precursors in the supersaturated state undergo the formation of clusters of nanoparticles. 3) Growth and Control – Nanoparticles are then further aggregated with size, shape, and controlled parameters, such as temperature, pressure, and type of precursor gases used. Such an effective chemical method can be easily operated using gas sensors to detect pollutants.

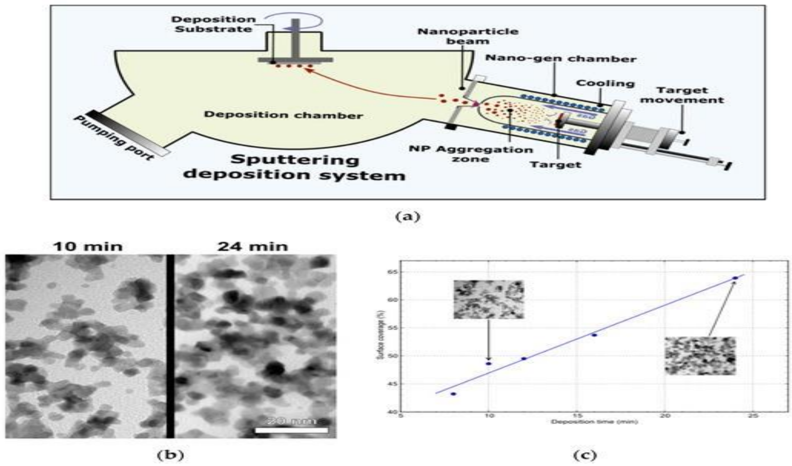

Fig: *Mechanism and synthesis of Gas phase nanomaterials*

Physical method is the most widely used methods for the synthesis of nanoparticles. Traditional methods, such as laser ablation and physical vapor deposition (paved), are costly and hazardous to the environment. Hence, Rise to green synthesis, that is, biological methods are the most effective and eco-friendly methods for controlling water pollution, Soil Remediation, Air pollution control, and waste management. *Plasma method* is the most useful method for water treatment. This will serve as the best option for remediation, such as in the industrial sector, for the removal of pollutants from water by utilizing nano-adsorbents, nano-catalysts and nano-membranes for water treatment. Compared to traditional remediation methods such as bioremediation, this method is very useful, time consuming and more efficient and effective. Polluted areas can also be treated using plasma-modified nanomaterials such as carbon nanotubes, which have the ability to remove salts and organic and inorganic pollutants from wastewater. One of the most important and polluting majors is dyes, which are very effective in degrading dyes from pollutants in wastewater and various types of plasma can be used in the industrial sector, such as thermal plasma, non-equilibrium plasma, plasma in liquid and atmospheric pressure plasma. The plasma method is more effective because, compared to other synthesis methods, it has a fast rate of synthesis. It has the ability to scale up industrial production and possesses a wide range of nanomaterials.

Mechanism of plasma method: The plasma method utilizes highly energetic plasma (ionized gas) to vaporize a precursor material, which then condenses into nanoparticles. One of the key points of plasma is that it provides a high-temperature and reactive species that enhances material synthesis and modification. In the Industrial Sector, both types of plasmas can be used. Thermal plasma (hot plasma) and nonthermal plasma (cold plasma). It goes through various stages, such as plasma generation, precursor introduction, Evaporation and Reduction, Nucleation and growth, and collection. Precursors, such as solid, liquid, or gaseous precursors (e.g. Metal powders. metal-organic compounds or gases such as CH_4 and NH_3. For the generation of plasma, a high-voltage or microwave/RF energy gas (Argon, Nitrogen, etc.) can help generate plasma. The Precursor can be injected into the plasma zone so that it vaporizes or decomposes the plasma energy into atomic or molecular species. As a result, vaporizes species after cooling and nucleates and grows into nanoparticles by maintaining parameters such as gas flow rate, pressure, plasma power control size, and morphology. Thus, nanoparticles can be easily collected on cold surfaces or filters using these methods.

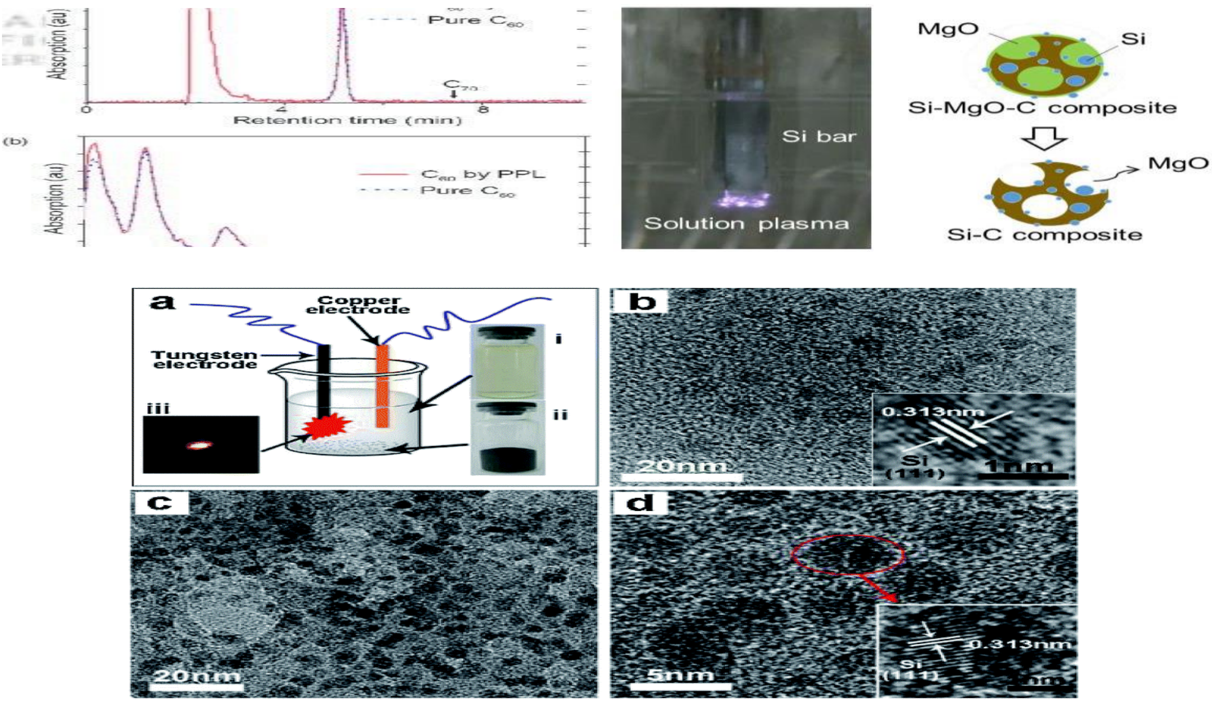

Fig: *Synthesis of nanoparticles using plasma method*

Plasma method synthesis of nanoparticles: 1) Photocatalytic nanomaterials (zinc oxide, titanium dioxide,) for water and air purification. 2) Magnetic Nanoparticles (e.g. Magnetite) to remove heavy metals and organic pollutants from wastewater. 3) Carbon-based nanomaterials for pollutant adsorption. *Reasons for effectiveness of plasma synthesis for remediation for environment:*

1. high purity and crystalline
2. controlled size and morphology
3. can be done at atmospheric pressure (no-thermal plasma),
4. scalability for industrial use.

Biological Method: The biological synthesis of nanoparticles is also known as *"Green synthesis"* Thus, it is eco-friendly and sustainable. This method includes biological aspects, such as plants, bacteria, fungi, algae, actinomycetes, and yeast as bionano factories to produce nanoparticles. Various methods have been introduced to initiate this natural process, including the following biological organism or extracts reduce metal ions into nanoparticles.

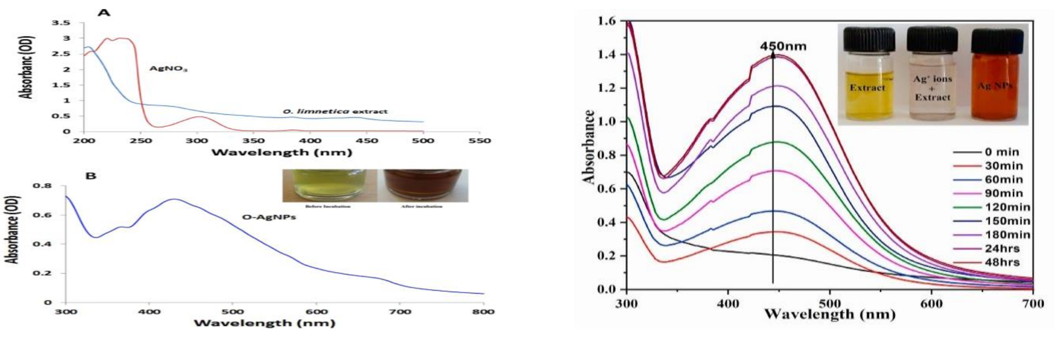

Fig: *Synthesis of nanoparticles using Root extract and Algae.*

Mechanism: 1) Selection of biological agents: Biological material may include plants (Leaf, Fruit, Root extracts), Bacteria, Fungi, Algae, Yeast. Each of these have capacity that these organisms contain enzymes, proteins, phenols, lipids, flavonoids etc. all sources of biomolecules etc. that will mediate nanoparticle formation. 2) Mechanism of Nanoparticle formation by bio reduction of metal ions, which helps to reduce biomolecules and convert metal ions to metal atoms. e.g. silver ions are reduced to silver atoms by microbial enzymes or other biological sources. 3) After Reduction, the atoms are aggregated to form nuclei. Thus, these nuclei were subjected to growth at a specific rate and size, which in turn formed nanoparticles. This formation is possible only under ideal pH, temperature and concentration of bio- reducing agents. 4) Biomolecules also have unique characteristics in that they can be used as capping agents, which prevent the aggregation and control of shape, size, and surface charge. Therefore, this step is very important for stabilizing the nanoparticles for environmental applications.

After synthesis of these nanoparticles can be used for:

a) Adsorption – Ability to adsorb heavy metals or organic pollutants from water or soil.
b) Catalytic Degradation: Some e.g. Iron or titanium nanoparticles catalyse the breakdown of harmful chemicals, such as Dyes, Pesticides, Chlorinated compounds Antimicrobial Action – Nanoparticles disrupt microbial cell walls, useful in waste water disinfection.

The pollution reduction percentage of biologically synthesized nanomaterials depends on the type of pollutant, nanoparticles used, application method, and environmental conditions. based on the above studies implies the efficiency of nanoparticles produced through biological methods.

1) *Heavy Metal Removal* (for example Lead, Cadmium, Chromium) – 80-90% reduction efficiency. Nanomaterials, such as iron oxide and plant-synthesized silver nanoparticles, can be used. Adsorption and precipitation were performed.
2) *Organic Pollutants* (e.g. Dyes, Pesticides, Hydrocarbons) with-70-95% reduction efficiency was found. Nanoparticles are synthesized using bacteria or plant extracts. Mechanism of photocatalytic degradation and oxidative breakdown
3) *Pathogenic Microorganisms in Water* (*Disinfection)* – 90-100% reduction efficiency. This was carried out using biogenic silver and copper nanoparticles.
4) *Air pollutants* – 60-80% and more) can be reduced by nanoparticles. Volatile organic compounds and harmful gases can be broken down by nanoparticles under UV or Sunlight irradiation.

Result

Remediation of the environment using nanomaterials for various pollutant levels can be determined. This indicates the potential of nanomaterials for remediation. Owing to the clarification of its potential, it will provide excessive use of nanomaterials to appropriate pollutants. This explains the importance of nanomaterials for ecosystems and all factors that depend on the ecosystem. It provides methods to treat various harmful substances that cause harm to the environment.

Physical method for nanomaterial: Carbon nanotubes (CNTs) have a high surface area and are effective for adsorbing heavy metals and organic pollutants. Graphene Oxide (GO) exhibits excellent adsorption capabilities for dyes, metals, and pharmaceuticals. Nano-zerovalent iron (Navi) can physically interact with contaminants in soil and groundwater. It possesses a higher strength for fast action and does not require chemical additives.

Chemical method for nanomaterials: Navi nanomaterials are highly reactive for breaking down chlorinated organic nitrates. Titanium dioxide nanoparticles help the photocatalytic degradation of organic pollutants under ultraviolet (UV) or visible light. Silver nanoparticles exhibit antimicrobial activity and catalytic degradation of certain pollutants. Such nanomaterials possess an effective strength for breaking down persistent pollutants.

Biological Methods for nanoparticles: Magnetic nanoparticles can support enzyme immobilization or microbial activity for targeted pollutant breakdown. Chitosan-based nanocomposites are biodegradable and compatible with microbial systems. Green synthesized nanoparticles are produced by plant extracts, which are more environmentally friendly and compatible with microbial ecosystems. These nanomaterials are eco-friendly and sustainable.

Conclusion:

Nanomaterials synthesized by various physical, chemical, and biological methods provide accurate action of different nanomaterials. It clarifies the actual mechanism of action for the remediation of different types of pollutants that cause harm to the environment and living organisms.

Chemical methods using Navi are potent for fast and efficient pollutant removal. Biological methods using biocompatible nanomaterials are promising for Eco-friendly and sustainable remediation. Physical methods offer rapid adsorption but often serve as a first step before further treatment.

Nanomaterials have revolutionized future approaches. Owing to the increased progress of humans, industrialization and consumption of reserves are present in nature.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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