**Role of Nanomaterials for the Air Pollution Management in Tribal Regions of Odisha**

**Abstract**

Nanomaterials are crucial in addressing air pollution through innovative solutions for detecting, filtering, and degrading harmful pollutants. Their exceptional properties high surface area, tenable morphology, and enhanced reactivity make them highly effective in applications such as gas sensing, catalytic converters, and photocatalysis. This review paper highlights the contributions of metal oxides, carbon-based nanomaterials, and nanocomposites to improving air quality in tribal region of Odisha. Recent advancements in nanotechnology have resulted in multifunctional materials that can both detect and degrade airborne contaminants, tackling the challenges of pollution monitoring and remediation. Integrating these nanomaterials into current air pollution control strategies offers promising opportunities to improve efficiency and reduce costs. Future research should concentrate on optimizing their performance and scalability to enable widespread adoption in air pollution management.

**Keywords**: Air pollution, Tribal areas, Nanomaterials, Pollutant reduction, Tribal health

**1.Introduction.**

Air pollution is the contamination of the atmosphere by harmful substances, including gases, particulates, and biological molecules, that affect health and the environment. Pollutants like particulate matter (PM2.5 and PM10), Carbon monoxide (CO), Ozone (O3), Black carbon (BC), Sulfur dioxide (SO2), and Nitrogen Oxides (NOx) can lead to serious health problems, including breathing difficulties and heart diseases. The main sources of air pollution from these pollutants are vehicles, factories, and burning fuels (World Health Organization. 2021). Particulate matter (PM) pollution consists of tiny particles and droplets in the air. These particles are classified as PM10 (10 micrometres or smaller) and PM2.5 (2.5 micrometres or smaller). Main sources of PM include car emissions, factories, and natural events like wildfires. Breathing in high levels of PM for a long time can lead to serious health problems, such as breathing and heart issues. PM also harms the environment by lowering air quality and damaging ecosystems. Reducing PM levels is important to protect both human health and the environment (Pope, C. A., et al. 2020). Air pollution occurs when harmful substances, such as gases, dust, and smoke, are released into the air. These pollutants come from various sources, like vehicles, factories, burning of crops, and deforestation. When these substances mix with the air, they can harm human health, animals, plants, and the environment. In many areas, pollution levels increase due to industrial activities, population growth, and improper waste disposal. Air pollution leads to respiratory diseases, climate change, and damage to ecosystems (Kumar, R., Sharma, S., & Singh, A. et al.,2024). The nanomaterials are materials that have at least one dimension between 1 and 100 nanometres (nm), which is extremely small. At this size, they behave differently from larger materials due to special properties like a higher surface area and unique effects from quantum physics (Gleiter, H. et al., 2022). These materials are classified by their size and shape at the nanoscale. Zero-dimensional (0D) materials, like nanoparticles, are nanoscale in all directions. One-dimensional (1D) materials, such as nanowires and nanotubes, are small in width and height but longer in length. Two-dimensional (2D) materials, like graphene and nanosheets, are thin but wide and long. Three-dimensional (3D) materials, like porous structures and nanocomposites, have nanoscale features throughout their structure. These types of nanomaterials can be designed for specific uses, including electronics, energy, medicine, and environmental cleanup (Li, X., Song, H., & Zhang, P. et al., 2023). The properties of nanomaterials such as Optical, Mechanical, Electrical and Chemical. Nanomaterials possess unique properties due to their small size, including optical, mechanical, electrical, magnetic and chemical properties. They are useful for imaging, sensors, electronics, energy storage, and medicine delivery due to their high reactivity and efficiency. Their unique features make them valuable in various fields and drive innovation (Zhang, H., Zhou, H., & Liu, L. et al., 2023). The Nanomaterials have diverse applications in medicine, energy, environmental, and electronics . They are used for targeted drug delivery, bioimaging, tissue engineering, solar cell efficiency, air and water purification, pollution control, and waste management. They also enable high-performance semiconductors, flexible displays, and advanced sensors in electronics, demonstrating their potential to revolutionize industries (Soni, A., & Verma, S. et al., 2023).

**2. Air Pollution in Tribal Regions of Odisha**

Odisha, located on India’s eastern coast, is home to 62 tribal communities, making up over 23% of the state’s population. These tribes mainly live in hilly and forested areas, which has helped them keep their unique culture and traditions alive. However, their remote locations make it hard for them to access important services like education, healthcare, and basic infrastructure. This creates challenges for their development and inclusion in wider progress. To overcome these issues, policies need to be created that respect their traditions while providing better access to modern facilities and services **(**Mohanty, S., & Behera, B., et al.,2023). Agriculture and forest resources are fundamental to the livelihoods of Odisha’s tribal communities. Traditional farming focuses on crops like rice, millets, and vegetables, while forests provide medicinal plants, timber, and other materials essential for sustenance and economic stability. These resources are also intertwined with cultural practices, including art, dance, and rituals, which sustain community identity. However, ongoing socio-economic challenges, such as poverty, food insecurity, and limited access to education and healthcare, exacerbated by geographical isolation and inadequate infrastructure, hinder their development (Nayak, R., & Patra, S., et al., 2023). The tribal communities in Odisha face significant challenges due to inadequate infrastructure. Poor connectivity in remote areas limits access to essential services like markets, healthcare, and education, leading to irregular school attendance and fewer opportunities for tribal children. Insufficient healthcare facilities and the prevalence of preventable diseases result in poor health outcomes. These infrastructural gaps exacerbate socio-economic struggles, perpetuating poverty and marginalization. Addressing these issues requires targeted interventions to improve connectivity, educational access, and healthcare services, enhancing the quality of life for tribal populations (Mohanty, A., & Das, B., et al., 2023), Striking a balance between development and preserving tribal heritage is crucial for sustainable growth in Odisha. Government initiatives must respect the cultural and social structures of tribal communities, ensuring they benefit from progress without losing traditional knowledge. Empowerment through education, skill development, and sustainable livelihoods is essential to improving socio-economic status. Inclusive development that protects tribal rights and traditions can facilitate long-term growth. Odisha has the potential to create a model of development that supports tribal populations while preserving their cultural legacy (Sahoo, S., & Mohanty, B., et al., 2023)

**2.1 Forest and Land Resources**

The tribal areas of Odisha are deeply interconnected with the state's forest ecosystems, which cover around 37% of its total area. These forests provide vital resources for tribal communities through activities like shifting cultivation, forest produce collection, and gathering medicinal plants. Additionally, forests hold significant cultural and spiritual importance, underpinning indigenous practices, rituals, and community structures. However, the commercialization of forest resources has disrupted traditional livelihoods, resulting in resource depletion, biodiversity loss, and reduced access to forest products. These shifts jeopardize the sustainability of traditional practices and the socio-economic well-being of tribal populations (Mishra, S. & Patra, S., et al.,2023).

**3. Geographical Region of Tribal Areas in Odisha**

The geographical region of tribal areas in Odisha, located in eastern India, is home to one of the largest tribal populations in the country.



**Figure 1. Geographical region of tribal areas in Odisha**

The state's diverse topography, comprising hills, plateaus, forests, rivers, and fertile plains, provides a unique environment for its tribal communities. These populations are mainly concentrated in the hilly and forested regions, particularly in districts like Bargarh, Sundergarh, Kalahandi, Sambalpur, and the southern areas of Koraput, Nabarangpur, and Gajapati. This geographical setting plays a key role in preserving their distinct cultural identities and traditional lifestyles (Behera, D., & Swain, B., et al., 2023).

**4.** **The sources of environmental pollution in the tribal areas of Odisha**

**4.1 Biomass Burning**

Biomass burning, the combustion of organic materials like wood, crop residues, and dung, is a significant global source of air pollution. It releases large amounts of particulate matter (PM₂.₅), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases such as carbon dioxide (CO₂) and methane (CH₄). This practice, common in agricultural and rural areas, deteriorates air quality, causes respiratory health issues, and contributes to climate change. In regions like Punjab, India, post-harvest residue burning exacerbates seasonal smog and health risks. Alternatives such as cleaner cooking technologies and residue management are vital for mitigating these effects (Sharma, S., et al., 2020).

**Figure 2. Biomass burning**

**4.2 Mining Activities**

The Mining activities of Odisha, particularly in tribal areas like Sundargarh, Sambalpur, and Kalahandi, the extraction and processing of minerals play a major role in causing air pollution. These operations release particulate matter (PM), Sulfur dioxide (SO₂), nitrogen oxides (NOₓ), and other harmful gases into the atmosphere. Dust from mining, transportation, and drilling can lead to respiratory diseases, while gases released into the air can cause acid rain and harm the environment large mining activities in India significantly impact air quality, causing health and environmental issues. Regulations and rules are needed to mitigate these harmful effects (Jha, M., & Pandey, S., et al., 2021).

**Figure 3. Mining Activities in tribal areas**

**4.3 Deforestation and Land Degradation.**

Deforestation and land degradation are critical environmental issues, especially tribal areas now a days cutting down trees and forests without replanting, where subsistence farming practices like slash-and-burn or 'Podu Chasa' are prevalent. In Odisha, these practices contribute to the loss of forest cover, causing soil erosion, reduced biodiversity, and diminished ecosystem services. The conversion of forests into agricultural land disrupts local ecosystems and accelerates climate change by releasing stored carbon into the atmosphere. (Panda, S. K., & Mohanty, S., et al.,2020).



**Figure 4. Deforestation and Land Degradation**

**5**. **Conventional methods for air pollution remediation in the tribal areas of Odisha.**

Traditional methods like plant-based air filters and smoke-reducing techniques in tribal areas of Odisha are cost-effective, accessible, and aligned with local knowledge. These sustainable practices, unlike advanced technologies, use locally sourced materials, making them more feasible for resource-limited areas and maintaining ecological balance (Panda et al., 2021). Traditional ecological knowledge in tribal communities offers sustainable methods for managing forests, farming, and natural resources, addressing pollution. By integrating traditional wisdom with modern scientific approaches, culturally respectful solutions can be developed, ensuring community participation and long-term success, enhancing environmental sustainability in tribal areas (Bora et al., 2020).

**5.1 Reforestation**

Tribal communities in Odisha understand the vital role forests play in maintaining air quality. Trees act as natural filters by absorbing pollutants such as carbon dioxide and releasing oxygen. These communities are actively involved in reforestation and tree planting efforts to combat air pollution. Additionally, the protection of sacred groves, which hold cultural or religious significance, contributes to environmental conservation and enhances air quality. By preserving these areas, tribal communities play a crucial role in safeguarding ecosystems and promoting cleaner air (Mishra et al., 2021).



**Figure** 5**. Reforestation**

**5.2 Agroforestry Practices**

Agroforestry, a traditional farming method that combines trees and shrubs with crops, is an effective approach for mitigating air pollution. It reduces soil erosion, enhances carbon sequestration, and serves as a natural barrier against dust and particulate matter. Tribal farmers in Odisha have long utilized agroforestry to maintain soil fertility and protect crops, indirectly contributing to improved air quality. By integrating trees into agricultural practices, these communities help reduce the environmental impact of farming while fostering sustainability (Rath et al., 2020).

**Figure 6.** **Agroforestry Practices**

**5.3 Biomass Management**

The Using biomass for cooking and heating leads to significant indoor air pollution in tribal areas. Traditional biomass management techniques, such as using improved cookstoves and setting community guidelines for fuelwood collection, help reduce harmful emissions. Although these methods do not completely eliminate pollution, they lower the release of harmful particles compared to open fires. Research has shown that such methods result in reduced indoor air pollution, contributing to better health and air quality (Kumar et al., 2024).

**5.4** **Traditional Knowledge in Fire Management**

Traditional fire management techniques are crucial in managing forest fires, which release harmful smoke, particles, and greenhouse gases, causing air pollution. Tribal communities use traditional methods like controlled burning and firebreaks to lower the risk of large-scale wildfires. These practices not only safeguard forests but also reduce harmful emissions and support ecological balance. Recent studies emphasize the importance of indigenous fire management in minimizing wildfire impacts and protecting biodiversity (**S**mith et al., 2023).

**5.5 Natural Air Filtration Systems**

The natural air filtration system Using natural materials like bamboo, clay, and jute to build homes and community spaces can improve indoor air quality. These materials naturally insulate and filter the air, reducing the entry of pollutants. Furthermore, planting vegetation around homes and villages helps act as a barrier against dust and harmful gases, improving the surrounding air. Research has shown that plants play a crucial role in absorbing pollutants and improving air quality in urban and rural areas (Sarkar et al., 2024).

**Figure 7.** **Natural air filtration systems**

**5.6 Community Participation in Pollution Control**

Community-driven initiatives, such as collective cleaning drives and awareness campaigns, are essential in managing air pollution. Tribal societies often use communal decision-making to tackle environmental issues. For example, many communities organize campaigns to reduce the open burning of agricultural residues, which is a major source of air pollution in rural areas. These initiatives not only help in reducing harmful emissions but also promote sustainable agricultural practices and community engagement. Recent studies highlight the positive impact of such community efforts on both air quality and local well-being (Chowdhury et al., 2023)

**6**. **Disadvantage of conventional method for air pollution Remedation in tribal areas of Odisha**

**6*.* 1. High Implementation Costs**

One of the key drawbacks of air pollution remediation methods in tribal areas of Odisha is the high cost of advanced technologies. Nanomaterial-based air filters, renewable energy systems, and air purification technologies often require significant initial investment, making them financially inaccessible for economically challenged tribal communities. Moreover, the maintenance and operational costs of these systems add to the burden, limiting their practicality and long-term sustainability in resource-constrained regions. These economic barriers hinder the adoption of advanced solutions, underscoring the need for affordable and culturally appropriate alternatives (Sharma et al., 2022)

**6.2. Lack of Technical Expertise and Training**

Air pollution control technologies often require specialized knowledge for installation, operation, and maintenance. In tribal areas of Odisha, where traditional practices dominate, there is a lack of technical expertise to manage advanced systems like biofiltration units or nanomaterial-based filters. Without adequate training and capacity building, these technologies may fail to function efficiently, increasing the risk of system failures. This gap in technical knowledge and support creates a significant barrier to adopting modern air pollution solutions, emphasizing the need for accessible, community-driven approaches (Patnaik et al., 2021)

**6.3. Cultural and Social Resistance**

Introducing advanced pollution control technologies can sometimes conflict with the traditional lifestyles of tribal communities. For instance, solar cookers or biogas plants may disrupt long-standing practices like cooking with firewood or biomass, which hold cultural significance. This can result in resistance to change, as communities may be reluctant to abandon their established ways of life. Without integrating modern solutions with traditional practices and respecting local customs, acceptance and participation in such programs may remain low, hindering widespread implementation (Sahoo et al., 2020).

**6.4. Environmental and Health Risks**

Certain air pollution control methods, like nanomaterial-based filters or biofilters, can pose unintended environmental and health risks. Improper disposal of used nanomaterials may contaminate soil and water, harming local ecosystems. Similarly, biofiltration systems can emit secondary pollutants or require additional energy, potentially negating their environmental benefits. In tribal areas, where ecosystems are tightly linked to community livelihoods, such risks can have severe consequences. Without adequate monitoring, regulation, and disposal mechanisms, these technologies could inadvertently introduce new challenges to the environment and public health (Kumar et al., 2021).

**7. Types of Nanomaterials used in air pollution Remedation**

Nanomaterials utilize various mechanisms for air pollution control, including adsorption, catalysis, and photocatalysis. Adsorption mechanisms rely on high surface area to trap pollutants like particulate matter and volatile organic compounds. Catalytic nanomaterials, such as platinum nanoparticles, facilitate oxidation or reduction reactions to neutralize harmful gases like NOₓ and CO. Photocatalysis, enabled by materials like titanium dioxide (TiO₂), uses sunlight or UV light to degrade pollutants into harmless byproducts. Additionally, nanomaterials in filters or membranes can efficiently remove particulate matter and pathogens. These mechanisms make nanomaterials effective in reducing air pollutants (Zhao et al., 2021)

**7.1. Metal oxides nanoparticles**

Metal oxide nanoparticles, such as titanium dioxide (TiO₂), zinc oxide (ZnO), and iron oxide (Fe₂O₃), have garnered attention for their exceptional properties, including high surface area, catalytic activity, and chemical stability. These characteristics make them ideal for diverse applications, particularly in environmental remediation. TiO₂ is extensively used for photocatalytic degradation of organic pollutants, ZnO for antimicrobial activities, and Fe₂O₃ for heavy metal removal from water. These nanoparticles are effective in addressing air and water pollution, contributing to sustainable environmental management (Khan, I., & Saeed, K., et al.,2021)

**7.1.1 Titanium Dioxide (TiO₂)**:

Titanium dioxide (TiO₂) nanoparticles can break down harmful pollutants when exposed to UV light. They are used in water and air purification systems to remove contaminants like volatile organic compounds (VOCs), helping to improve air quality. TiO₂ works better depending on factors such as particle size, surface area, and catalysts. Recent research focuses on improving TiO₂'s effectiveness by adding metals or combining it with other materials. For example, TiO₂ coatings on building surfaces can help reduce smog and improve air quality in tribal areas, making the environment cleaner and safer for people. **(**Sharma, S., & Singh, D., et al,2022).

**7.1.2 Zinc Oxide (ZnO)**:

Zinc oxide (ZnO) nanoparticles effectively break down harmful pollutants like dyes, pesticides, and volatile organic compounds when exposed to UV light, creating reactive oxygen species (ROS) that convert them into safer compounds. With a high surface area, ZnO is used in environmental applications for example air purifiers to reduce indoor air pollution (Chakraborty, S., & Das, S., et al.,2022).

**7.1.3** **Iron Oxide (Fe₂O₃)**:

Iron oxide nanoparticles (Fe₃O₄) are effective in cleaning polluted water due to their ability to capture heavy metals and break down organic pollutants. They are cost-effective and sustainable, suitable for photocatalytic coatings, air filtration systems, and pollution absorption materials, thereby improving air and water quality and reducing harmful pollutants.

(Singh, R., & Kumar, A., et al.,2022)

**7.2. Carbon-Based Nanomaterials**

Carbon-based nanomaterials, such as carbon nanotubes (CNTs), graphene, and activated carbon, are highly effective at removing pollutants from the air and water. These materials have a large surface area and can adsorb harmful substances like heavy metals, organic pollutants, and dyes. Activated carbon is commonly used in air purifiers to capture gases and particulate matter. CNTs and graphene also show promise in catalytic applications for pollutant breakdown. For example, carbon-based materials are used in gas sensors to detect pollutants, photocatalytic coatings to break down pollutants on surfaces, and in reducing smog by absorbing harmful gases (Kumar, P., & Singh, N., et al.,2022).

**7.2.1 Carbon Nanotubes (CNTs)**:

Carbon nanotubes (CNTs) are studied for environmental use because they are strong, heat-resistant, and conduct electricity well. They are very good at cleaning the air and water by removing harmful pollutants like heavy metals and chemicals. With their large surface area, CNTs can trap pollutants and help break down harmful substances. Researchers are trying to make CNTs even better at cleaning by adding special features. For example, CNTs can be used to filter out harmful gases like carbon monoxide from polluted air, making the air safer to breathe (Zhang, Y., & Li, X., et al.,2023)

**7.2.2 Graphene**:

Graphene is a thin layer of carbon atoms arranged in a flat pattern, and it has great potential to help clean the environment because of its large surface area and reactivity. It can absorb harmful pollutants like metals, chemicals, and gases. For example, graphene can help remove harmful gases from the air, and when combined with titanium dioxide (TiO₂), it can break down pollutants using light. Graphene can also be used in air filters and sensors to detect and monitor pollution in real time (Li, J., Wang, H., & Zhang, T., et al., 2023).

**7.2.3 Activated Carbon**:

Activated carbon, a regular material, can be treated at the nanoscale to make it better at absorbing pollutants. This makes it useful for cleaning the air, treating wastewater, and cleaning soil. By improving its performance at the nanoscale, activated carbon is especially good at removing pollutants from water and air. For example, nanoscale-activated carbon can be used in air filters to remove harmful gases like volatile organic compounds (VOCs) from polluted indoor air, improving air quality (Kumar, R., Sharma, P., & Gupta, V., et al., 2023).

**8.** **Different technologies for air pollution remediation in the tribal areas of Odisha.**

Air pollution in tribal areas of Odisha is a growing concern, driven by deforestation, mining, biomass burning, and outdated agricultural practices. Effective mitigation requires a blend of advanced technologies and localized solutions. Innovative methods such as nanotechnology-based filters, biofiltration systems, and renewable energy technologies offer transformative potential to reduce pollution. These approaches not only address environmental challenges but also align with the sustainable and socio-cultural framework of tribal communities, promoting community participation and long-term impact. A tailored strategy combining modern science with traditional knowledge is essential for meaningful outcomes (Mishra et al., 2021).

**8.1 Nanotechnology for Air Filtration**

The study explores the use of nanomaterials in the field of nanotechnology for air filtration., especially metal oxides like titanium dioxide (TiO₂) and silica nanoparticles, hold promise for air pollution control. These materials can be used in air filters and photocatalytic converters to remove pollutants like dust, harmful gases, and volatile organic compounds (VOCs). Nanocoated air filters effectively trap fine particles from biomass burning, a significant source of air pollution in tribal areas. Implementing these systems in communities can enhance air quality, save energy, and be cost-effective (Zhao, Y., & Chen, X., et al., 2020).

**8.2 Biofiltration Techniques**

Biofiltration is a sustainable and efficient method that uses microbes to remove harmful pollutants from the air. This method can be integrated with traditional knowledge, such as the use of bamboo groves or other native plant species known for their air-purifying properties. The Dongria Kondh and other tribal groups in Odisha utilize plants for environmental reasons, making biofiltration a culturally appropriate practice. Enhancing these natural processes with technological inputs can help address emissions from small-scale industries and household combustion, improving air quality in rural and tribal areas (Sharma, R., & Kumar, M., et al.,2021)

**8.3 Renewable Energy for Pollution Reduction**

Renewable energy sources have the potential to significantly reduce pollution, such as solar and wind power, can significantly reduce reliance on fossil fuels and biomass, thereby mitigating air pollution. Solar cookers and community-based biogas plants offer cleaner alternatives to traditional cooking methods, which are major sources of indoor air pollution. The introduction of these technologies through government programs and local NGOs ensures active participation and ownership among tribal communities. By providing access to clean energy alternatives, these systems help reduce emissions and improve public health outcomes in tribal areas (Singh, P., & Gupta, A., et al., 2020**)**

**9. Challenges in Tribal Areas of Odisha**

**9.1 Poverty**

Poverty in Odisha's tribal areas is a serious problem that affects daily life. Most tribal families depend on farming and forest resources for their income. However, poor farming methods, deforestation, and damaged land reduce their earnings. Many people face seasonal unemployment and have few other job options, making their economic situation worse. These challenges create instability and make it difficult for families to improve their living conditions. Finding sustainable solutions, such as better farming techniques and access to new livelihoods, is essential to help reduce poverty and improve the quality of life in these communities (Panda, B. et al., 2022)

**9.2 Educational:**

Education is a key tool for personal and community development, but it faces many challenges in tribal areas of Odisha. Schools are often far from villages, so children find it hard to attend regularly. Many children drop out of school early due to poverty and the need to help their families. The lack of proper schools and trained teachers makes learning harder. Language differences also create difficulties, as tribal languages are different from the language used in schools, making it tough for students to understand lessons (Sahoo, S. K., & Sahoo, D.et al., 2021).

**9.3 Healthcare**

The health care in tribal areas of Odisha, there are not enough healthcare facilities, and many villages don't have basic medical services. This means people often don't get the treatment they need. Many children suffer from malnutrition because of limited access to healthy food, poor sanitation, and a lack of knowledge. As a result, tribal communities are more likely to get sick, especially with infections and preventable diseases. The lack of healthcare, poor nutrition, and high levels of illness lead to shorter life expectancy and worse health. It's important to improve healthcare services and raise awareness in these areas (Panda, P. K., & Das, M. et al., 2023).

**10.Future Scope and Opportunities**

The future Scope of tribal communities lies in the empowerment of the youth through education and skill development programs. Schools that integrate tribal languages with modern curricula can help bridge educational gaps. Vocational training in sectors such as agriculture, handicrafts, and technology can provide new opportunities for economic advancement. Encouraging local entrepreneurship, particularly in handicrafts and sustainable agriculture, can also foster self-support.

* 1. **. Improved Healthcare Access:**

Leveraging mobile health units, telemedicine, and local healthcare workers can help improve access to healthcare in remote tribal areas. Integration of traditional medicine with modern healthcare systems can create more culturally relevant and effective healthcare models. Public health campaigns to raise awareness about sanitation, hygiene, and preventive healthcare practices can further improve the health outcomes of these communities.

**10.2. Utilizing Technology for Environmental Sustainability:**

Nanomaterials and other innovative technologies can play a crucial role in pollution control and environmental sustainability. In tribal areas of Odisha, nanomaterials can be used in air and water purification systems to reduce the impact of pollution on public health. Green technologies, including renewable energy solutions like solar power, can be introduced to reduce reliance on non-renewable resources. Additionally, the promotion of sustainable agricultural practices can help conserve the environment and improve food security.

**11. Conclusion**

Air pollution poses a critical challenge in Odisha’s tribal regions, impacting health, degrading the environment, and causing economic losses. The rise in harmful pollutants such as particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NOx), and sulfur dioxide (SO2) necessitates effective interventions. Traditional pollution control methods are often inadequate in these remote areas due to limited infrastructure and resources. Nanomaterials, with their exceptional properties like high surface area, reactivity, and customizable features, offer innovative and sustainable solutions to manage air pollution in these regions. Metal oxide nanoparticles, such as TiO₂, ZnO, and SnO₂, are particularly effective in degrading gaseous pollutants like NO₂, SO₂, and VOCs. Acting as photocatalysts, these nanoparticles facilitate pollutant breakdown under UV or ambient light, reducing their concentration and mitigating health risks. Additionally, advanced air filtration systems incorporating carbon nanotubes (CNTs), graphene oxide (GO), and nanoporous materials excel in capturing fine particulate matter (PM2.5 and PM10), a major concern in these areas. These nano filters outperform conventional systems, offering higher efficiency and longer service life. Nanomaterials also enable real-time air quality monitoring through low-cost, portable gas sensors. These devices can detect hazardous gases like carbon monoxide (CO) and ammonia (NH₃), empowering local communities to take timely protective measures. Moreover, green synthesis methods for nanomaterials, using natural resources like plants and fungi, provide eco-friendly and affordable alternatives that align with tribal traditions. This approach not only reduces environmental impact but also fosters local economic growth.While nanomaterials hold immense promise for air pollution control, challenges such as scalability, affordability, and public awareness must be addressed. Collaborative efforts among scientists, policymakers, and communities are essential to ensure these technologies are accessible, effective, and adapted to the needs of Odisha’s tribal regions.

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