Land and Air Pollution: Sources, Impacts, and Engineering Control Strategies

smv@mcehassan.ac.in | amritk.iyursmilx@gmail.com | pymithun117@gmail.com | msr610742@gmail.com | bindutanu9@gmail.com

Sushma M V, Amrit Kumar Kamble, Mithun P Y, Tanushree M, Manya S R

Malnad College of Engineering, Hassan, Karnataka, India Department of Computer Science and Engineering (Artificial Intelligence and Machine Learning),

Sushma M V (Assistant Professor); all other coauthors are students

Abstract— Land and air pollution are often discussed as separate environmental problems, but in real settings they behave more like parts of the same system. Industrial activity, transport, agriculture, mining, construction, energy use, and poorly managed waste can release pollutants to the atmosphere while also changing the quality and function of land. This review examines major air pollutants and soil contaminants, their sources, environmental pathways, health and ecological effects, monitoring approaches, and engineering responses. Along with established technologies such as electrostatic precipitators, fabric filters, wet scrubbers, catalytic emission control, and flue-gas treatment, the paper considers source segregation, resource recovery, engineered landfills, leachate and landfill-gas management, bioremediation, phytoremediation, soil stabilization, and cleaner transport. Particular attention is given to the links between the two media: open waste burning, windblown dust, atmospheric deposition, landfill emissions, contaminated runoff, and pollutant transfer through food and water. The review also proposes a practical monitoring-to-control workflow and a decision framework for selecting soil-remediation methods. Rather than treating pollution control as a collection of isolated devices, the paper argues for a hierarchy that begins with prevention and cleaner production, followed by recovery, treatment, remediation, and controlled disposal. The overall objective is not simply to move pollutants from one compartment to another, but to reduce their generation, restrict their movement, and verify that environmental risk is actually decreasing.

I. INTRODUCTION

Pollution is easiest to understand when it is viewed as a change in the environment that interferes with normal ecological or human activity. Air pollution changes the composition of the atmosphere, while land and soil pollution change the physical, chemical, or biological condition of the ground. In practice, however, the same activity can affect both. A poorly controlled industrial process may emit particles to the air and leave contaminated residues on land. A construction site can generate airborne dust while also disturbing soil. Waste placed on an open dump can produce litter and leachate, but the same waste may also release smoke when it is burned. These examples show why environmental engineering works best when pollution pathways are considered together rather than one medium at a time [1]–[5].

The health significance of air pollution is particularly clear for fine particulate matter and several reactive gases. The World Health Organization (WHO) identifies $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide as key pollutants for which health-based guideline levels have been developed [1], [2]. The updated WHO guidelines also reflect a stronger body of evidence showing health effects at lower concentrations than previously recognized [1], [6]. For land, the concern is not limited to visible waste. Heavy metals, pesticides, petroleum hydrocarbons, plastics, solvents, and other contaminants can remain in soil, change its properties, move into water, or enter food chains [4], [5].

From an engineering perspective, the central question is therefore not simply 'How can a pollutant be removed?' but 'Where is the pollutant generated, how does it move, who or what is exposed, and which intervention prevents the pathway most effectively?' This shift in thinking leads naturally to source reduction, cleaner production, containment, monitoring, treatment, recovery, and remediation as complementary actions.

A. Review Scope and Approach

This paper is a narrative review built around the supplied literature on air pollution, soil pollution, Indian land degradation, and environmental management, supplemented with recent authoritative guidance and engineering literature. The discussion is organized around five questions: what pollutants are important, where they originate, how they move between environmental compartments, how they are measured, and which engineering controls are appropriate. The emphasis is on concepts that can be understood and applied by undergraduate engineering students without assuming specialist environmental-engineering training.

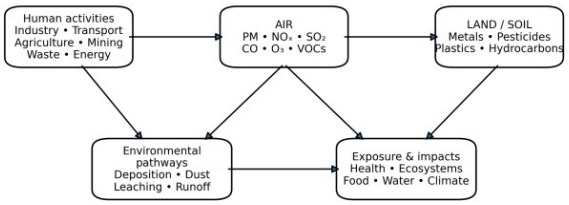


Fig. 1. Conceptual relationship among pollution sources, environmental pathways, exposure, and impacts.

II. AIR POLLUTION

A. Major Pollutants and Their Behaviour

Air pollutants can be grouped into primary pollutants, which enter the atmosphere directly from a source, and secondary pollutants, which form after chemical reactions in the atmosphere. This distinction matters because controlling a secondary pollutant often requires reducing its precursor gases rather than attempting to capture the pollutant after it has formed.

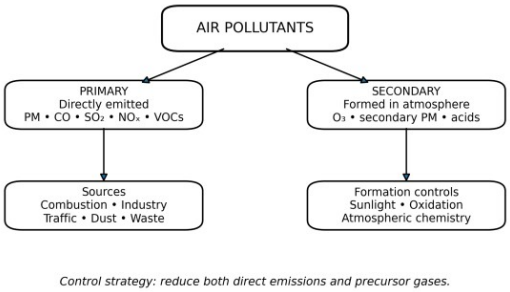


Fig. 2. Primary and secondary air pollutants and the main factors governing their formation.

Particulate matter is commonly described by aerodynamic size. PM_{10} includes particles with aerodynamic diameter up to approximately 10 µm, while $PM_{2.5}$ represents a finer fraction up to approximately 2.5 µm. Fine particles can penetrate deep into the respiratory system, and the smallest fractions are associated with cardiovascular and respiratory effects [1], [2]. Particles may contain mineral dust, soot or black carbon, sulfates, nitrates, ammonium, organic compounds, metals, and biological material. Their composition depends strongly on the source and atmospheric processing.

Nitrogen oxides (NO_x), especially NO_2, are closely associated with combustion in vehicles, industrial equipment, and power-generation systems. Sulfur dioxide (SO_2) is released when sulfur-containing fuels or mineral ores are processed. Carbon monoxide (CO) is produced by incomplete combustion and is particularly important where combustion occurs with poor ventilation or insufficient oxygen. Ground-level ozone (O_3) is different from stratospheric ozone: it is a secondary pollutant produced through atmospheric reactions involving precursor gases and sunlight. Volatile organic compounds (VOCs) come from fuel evaporation, solvents, coatings, industrial processes, and incomplete combustion and can participate in photochemical pollution [2], [3].

Other pollutants can be important in specific locations. Lead, arsenic, nickel, benzene, ammonia, and benzo[a]pyrene are included among parameters considered in India's ambient-air quality framework [7]. The importance of any one pollutant depends on the local source mix, population exposure, meteorology, and industrial activity. This is why a control strategy designed for one city or facility should not automatically be copied to another.

B. Sources of Air Pollution

Transportation is a major urban source because engines and associated activities can release NO_x, CO, hydrocarbons, particles, and resuspended road dust. The actual emission profile depends on engine technology, fuel, maintenance, operating conditions, traffic congestion, and emission-control equipment. Industrial facilities add emissions from fuel combustion, material processing, storage and handling, chemical reactions, and leaks. Construction, quarrying, mining, and movement of vehicles on unpaved surfaces can produce substantial dust.

Agriculture contributes through field operations, soil disturbance, fertilizer use, livestock emissions, and the burning of crop residues. Waste management can contribute through open burning, landfill gas, transport of waste, and poorly controlled treatment processes. Household combustion can also be important, especially where solid fuels are used without adequate emission controls. Natural sources such as windblown dust, wildfires, sea salt, and biological particles complicate the picture because measured concentrations may contain both human and natural contributions [2], [6].

C. Health and Environmental Effects

The effects of air pollution depend on concentration, duration, pollutant chemistry, particle size, and individual susceptibility. Exposure to particulate matter is associated with respiratory and cardiovascular effects, while nitrogen dioxide and ozone can contribute to airway irritation and respiratory stress [1]–[3]. Long-term exposure can be more difficult to notice because the effects may develop gradually rather than appearing as an immediate symptom.

Environmental effects are equally important. Photochemical smog can reduce visibility and damage vegetation. Sulfur and nitrogen compounds can contribute to acidification and nutrient imbalance. Deposited particles can alter soil and water chemistry, while black carbon and other short-lived climate pollutants can influence radiative forcing. The important engineering lesson is that an air pollutant does not necessarily remain an air problem; once deposited, it can become part of a land or water contamination problem.

III. LAND AND SOIL POLLUTION

A. Sources and Contaminants

Land pollution is often visible as litter, dumps, degraded surfaces, or abandoned industrial areas, but soil contamination can exist even when the surface looks clean. The 2025 soil-pollution review supplied for this paper identifies industrial activity, agriculture, urbanization, waste disposal, and other human activities as important sources and discusses heavy metals, pesticides, hydrocarbons, plastics, solvents, and biological contaminants [4].

Industrial contamination can arise from spills, leaks, process residues, storage failures, atmospheric deposition, and disposal of solid or liquid wastes. Mining can remove topsoil, disturb soil structure, expose minerals, generate waste rock and tailings, and create pathways for acid drainage or metal release. Agricultural land may receive fertilizers, pesticides, irrigation-related salts, and residues from repeated chemical use. Urban areas receive mixed pressures from construction, traffic, sewage, waste handling, small industries, and accidental releases [5].

Municipal waste becomes a land-pollution problem when collection, segregation, treatment, and final disposal are inadequate. Organic material can decompose and generate gas, while water moving through waste can form leachate. If the disposal area lacks appropriate containment and drainage, contaminants can migrate into surrounding soil and groundwater. The risk therefore depends not only on what is thrown away, but also on how the waste is handled over time [8], [9].

B. Environmental and Health Impacts

Soil is a living system rather than an inert storage medium. Contamination can alter pH, salinity, organic matter, structure, water retention, nutrient availability, and microbial activity. Changes in these properties can reduce soil productivity and make the land more vulnerable to erosion and further degradation. The Indian soil-degradation literature also points to interacting pressures such as inappropriate agricultural practices, deforestation, mining, industrial waste, overgrazing, and urban expansion [5].

Contaminants can move through several routes. Dissolved chemicals may leach downward toward groundwater. Runoff can transport contaminated sediment into streams or reservoirs. Wind erosion can turn contaminated soil into airborne dust. Plants can take up some contaminants, creating a potential pathway from soil to food. People may also be exposed directly through contact with contaminated soil or inhalation of resuspended particles. These pathways make risk assessment more useful than simply measuring the concentration of a contaminant in isolation.

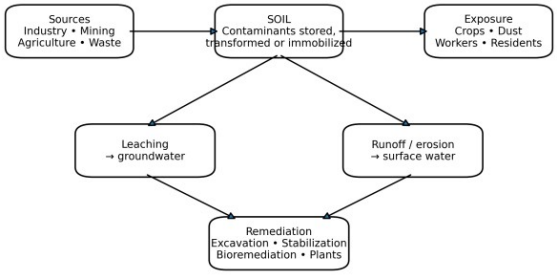


Fig. 3. Major pathways by which land and soil contamination can move toward water, air, ecosystems, and human exposure.

C. Soil Quality Is More Than Chemical Cleanliness

A useful improvement in pollution management is to distinguish between contaminant removal and restoration of soil function. A soil can contain a reduced concentration of a target contaminant and still have poor structure, low biological activity, or limited fertility. Conversely, a contaminant may remain present but be strongly immobilized so that exposure and mobility are greatly reduced. For this reason, remediation objectives should be defined clearly: removal, degradation, immobilization, exposure reduction, or recovery of soil function.

This distinction is particularly important for metals. Unlike biodegradable organic compounds, metals cannot be destroyed; they can only be removed, separated, transformed into less mobile forms, or otherwise managed. Recent reviews describe mechanisms such as biosorption, bioaccumulation, biotransformation, bioprecipitation, and plant-assisted stabilization as parts of the broader bioremediation toolbox [14].

IV. INTERACTION BETWEEN AIR AND LAND POLLUTION

A. Open Waste Burning

Open waste burning is one of the clearest examples of a land-management problem becoming an air-quality problem. Mixed waste may release particles, carbon monoxide, VOCs, and other combustion products directly into the atmosphere. At the same time, the ash and unburned residue remain on the ground and may contain concentrated contaminants. Preventing open burning therefore produces a double benefit: less uncontrolled emission and less contaminated residue.

B. Landfills and Gas Generation

Organic waste placed in oxygen-limited landfill conditions can generate landfill gas, commonly containing methane and carbon dioxide. The engineering response is not simply to cover the waste. A well-designed facility should control surface water, collect leachate, manage gas migration, and monitor the site. Where practical, biodegradable waste can be diverted to composting or anaerobic digestion, reducing the amount of organic material that requires long-term landfilling [8], [9].

C. Dust from Degraded Land

Exposed soil is an air-pollution source when wind or mechanical activity lifts particles from the surface. Mining areas, construction sites, unpaved roads, agricultural fields, and degraded land can all contribute dust. Dust control is therefore partly a land-management problem. Revegetation, surface stabilization, paving, moisture management, traffic control, and proper stockpile design can reduce both soil loss and airborne particulate matter.

D. Atmospheric Deposition

The transfer also occurs in the opposite direction. Particles and gases released into the atmosphere can return to land through dry deposition or precipitation. Over time, repeated deposition can change soil chemistry and introduce contaminants far from the original emission source. This is one reason monitoring programs should not assume that a contamination boundary is fixed; atmospheric transport can create diffuse patterns that require spatial assessment.

V. MEASUREMENT, MONITORING, AND DATA QUALITY

A. Air-Quality Monitoring

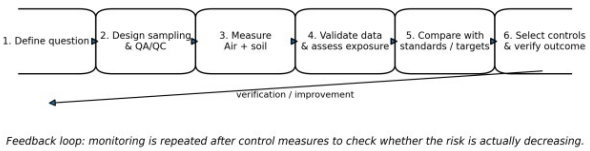
Monitoring is the bridge between pollution theory and engineering decisions. An air-quality program should begin by defining the question: is the objective compliance, exposure assessment, source identification, trend analysis, or evaluation of a control device? The answer determines where sensors are placed, how frequently samples are collected, which pollutants are measured, and what quality-control procedures are required.

Reference-grade monitoring stations provide high-quality measurements but are relatively expensive and require maintenance. Low-cost sensors can increase spatial coverage, but their readings may be affected by temperature, humidity, cross-sensitivity, drift, and calibration quality. A practical approach is to use validated reference instruments to calibrate and periodically check lower-cost networks rather than treating every sensor reading as equally reliable.

B. Soil Monitoring

Soil sampling must account for spatial variability. Contamination may be concentrated near a spill, industrial boundary, drainage channel, waste pile, storage area, or former process unit. A good sampling plan therefore records depth, location, land use, soil type, and likely source history. Laboratory measurements may include pH, electrical conductivity, organic carbon, nutrients, metals, hydrocarbons, pesticides, and other site-specific indicators. Remote sensing and geographic information systems can add valuable information on land-cover change, vegetation stress, erosion, and mining disturbance, but laboratory measurements remain necessary when chemical concentrations must be quantified.

C. A Practical Monitoring-to-Control Workflow



Feedback loop: monitoring is repeated after control measures to check whether the risk is actually decreasing.

Fig. 4. Monitoring workflow linking environmental measurement to control selection and verification.

The most useful monitoring system is one that closes the loop. Data should identify a problem, guide a control measure, and then be collected again to determine whether the control worked. For example, if a factory's particulate concentration rises, the investigation should move from the measured concentration to process conditions, filter pressure drop, maintenance history, and possible bypass or leakage. Similarly, a contaminated site should be re-sampled after remediation to verify whether the contaminant was actually removed, degraded, or immobilized.

D. Standards and Regulatory Context

Environmental standards provide a common basis for judging measured concentrations. India's National Ambient Air Quality Standards framework covers a broader set of pollutants than the six WHO guideline pollutants, including PM_{10}, $PM_{2.5}$, NO_2, SO_2, O_3, CO, lead, ammonia, benzene, benzo[a]pyrene, arsenic, and nickel [7]. The WHO Global Air Quality Guidelines are health-based

recommendations rather than legally binding standards [1], [6]. The WHO Air Quality Standards database was updated in January 2026 and provides a current comparative reference for national air-quality standards [10]. Because national rules and guidance can change, final compliance decisions should always use the latest applicable notification from the responsible authority.

VI. ENGINEERING CONTROL STRATEGIES

A. Particulate Control

Particulate control starts with source reduction. If a process can be enclosed, a dusty material can be handled with less drop height, or a fuel can be replaced with a cleaner alternative, these changes should be considered before relying only on a downstream collector. Where capture is required, cyclones, fabric filters, electrostatic precipitators (ESPs), and wet scrubbers are common choices. The correct device depends on particle size, gas temperature, moisture, chemistry, pressure drop, and the desired outlet concentration.

ESPs electrically charge particles and collect them on oppositely charged surfaces. Fabric filters pass the gas through porous media and retain particles on the filter surface. Wet scrubbers transfer particles and selected gases into a liquid phase. Recent work continues to improve ESP performance for fine and submicron particles through multistage configurations, agglomeration, hybrid filtration, and better modelling [15]. This illustrates an important engineering principle: mature technologies can still improve when operating conditions and particle behaviour are understood more precisely.

B. Gaseous-Pollutant Control

Sulfur dioxide can be reduced through fuel switching, fuel desulfurization, process modification, and flue-gas desulfurization. Nitrogen oxides can be controlled through combustion optimization, staged combustion, selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR), and vehicle after-treatment. VOCs may be managed through leak detection and repair, vapor recovery, adsorption, condensation, thermal or catalytic oxidation, and improved process containment. Reviews of industrial flue-gas treatment emphasize that technology selection must consider pollutant properties, process conditions, energy use, and the characteristics of the resulting waste or by-product [16].

C. Cleaner Transport and Fuels

Transport control is most effective when several measures work together. Cleaner fuels and efficient engines reduce emissions at the source; catalytic after-treatment controls pollutants that remain in exhaust; inspection and maintenance prevent deterioration; and public transport and demand management can reduce the number of high-emitting vehicle-kilometres. Electrification can remove tailpipe emissions at the point of use, although the overall environmental benefit still depends on how electricity is generated and how vehicles and batteries are manufactured and managed at end of life.

D. Waste Segregation and Resource Recovery

Waste segregation is an engineering control because it changes what happens to waste after it is discarded. Keeping biodegradable, recyclable, and hazardous fractions separate improves the feasibility of composting, anaerobic digestion, recycling, and specialized treatment. The Solid Waste Management Rules, 2016 establish duties related to segregation and management in India [8]. In practice, however, the success of segregation depends on the entire chain: source separation, collection, transport, material recovery, markets for recovered materials, treatment facilities, and final disposal.

E. Engineered Landfills and Legacy Waste

A landfill should be treated as an engineered containment system rather than a simple hole in the ground. Key features include an appropriate liner or containment system, leachate collection and management, stormwater control, gas management, operational cover, slope stability, and post-closure monitoring. For old dumpsites, biomining and bioremediation can be considered where technically and environmentally appropriate. CPCB guidance under the Solid Waste Management Rules emphasizes the assessment and treatment of legacy waste rather than allowing uncontrolled open dumping to continue [9].

F. Soil Remediation

Remediation should be chosen after site characterization and risk assessment. Excavation and removal can be fast for localized contamination but may be costly and can transfer contaminated material elsewhere. Stabilization or solidification can reduce contaminant mobility. Soil washing can separate contaminants under suitable conditions. For volatile organic contaminants, soil-vapor extraction may be appropriate at suitable sites. Biological approaches can be attractive when contaminants are biodegradable or when the objective is to immobilize or reduce exposure rather than physically remove every molecule [13], [17].

Bioremediation uses microorganisms and biological processes to transform suitable contaminants. Approaches may be in situ or ex situ and can involve biostimulation, bioaugmentation, land farming, composting, biopiles, or bioreactors. Recent reviews emphasize that performance depends on contaminant type, bioavailability, temperature, pH, moisture, oxygen, nutrients, soil structure, and microbial activity [13], [14]. Phytoremediation uses plants to extract, stabilize, degrade, or otherwise manage contaminants. It can be useful over large, shallow areas with relatively suitable contaminant concentrations, but it is not a universal solution and requires careful plant selection and long-term management [17].

VII. INTEGRATED POLLUTION MANAGEMENT

A. The Control Hierarchy

A strong pollution-control program follows a hierarchy rather than beginning with the most visible treatment device. Prevention and source reduction are preferred because they avoid creating a pollutant in the first place. Next come reuse, recycling, and recovery; treatment and end-of-pipe controls are used for what remains; remediation addresses contaminated environments; and controlled disposal is reserved for residual material that cannot reasonably be recovered or treated.

B. Avoiding Pollution Transfer

One of the most common weaknesses in environmental control is solving one problem by creating another. Capturing dust in a filter is useful, but the collected dust must still be handled safely. Wet scrubbing can remove gases and particles from air, but it creates a liquid or sludge stream that requires treatment. Soil excavation can reduce risk at one location but transfers the material to another location unless final management is controlled. Therefore, every engineering solution should include a secondary-waste and life-cycle check.

C. Circular Environmental Engineering

Circular approaches try to keep materials in productive use for longer while reducing waste and pollution. Examples include industrial symbiosis, recovery of useful materials from waste, composting of suitable organic fractions, use of recovered water where safe, and product designs that reduce material losses. The objective is not recycling for its own sake; the objective is to reduce total resource extraction and pollution while maintaining the required function and safety.

VIII. INDIAN CONTEXT AND PRACTICAL IMPLEMENTATION

India provides a useful setting for integrated pollution management because rapid urbanization, transport growth, industrial activity, agriculture, mining, construction, and waste generation can operate in the same landscape. The reviewed literature on Indian soil degradation shows that land degradation rarely has a single cause; physical erosion, inappropriate land use, industrial activity, mining,

and urban expansion can interact [5]. This makes sector-specific controls necessary, but it also makes coordination between agencies and land uses important.

At the municipal level, an integrated plan can begin with waste characterization and source segregation, followed by material recovery, biological treatment of suitable organic waste, and scientifically managed disposal of residuals. At the industrial level, a similar logic can be applied: map emission and waste sources, reduce generation, capture pollutants close to the source, treat captured streams, recover useful materials where feasible, and monitor both emissions and surrounding environmental media.

For an engineering student or early-career practitioner, a practical project can therefore be structured around a simple sequence: identify the source, draw the pathway, measure the pollutant, estimate the exposure, choose the control, calculate or estimate performance, and verify the result. This approach is more transferable than memorizing individual pollution-control devices.

IX. CHALLENGES AND FUTURE SCOPE

Pollution management remains difficult because sources are distributed across sectors and environmental compartments. Air concentrations change with wind, temperature, atmospheric chemistry, season, and regional transport. Soil contamination changes with depth, land use, drainage, soil texture, organic matter, and historical activity. A monitoring program that ignores these variations can produce a misleading picture even when the individual instruments are accurate.

A second challenge is the growing number of low-cost sensors and digital tools. Sensor networks, satellite imagery, geographic information systems, mobile monitoring, and data analytics can make environmental information more accessible, but they also create new responsibilities for calibration, validation, data management, and uncertainty analysis. Machine-learning models can help identify patterns and predict pollution, but their outputs should be tied to physical measurements and understandable environmental mechanisms rather than treated as unquestionable predictions.

Future engineering work is also likely to combine pollution control with climate and resource objectives. Examples include energy-efficient air-pollution-control devices, recovery of materials from industrial residues, low-carbon remediation, biochar and other soil amendments where scientifically justified, plant–microbe remediation systems, and hybrid monitoring networks. Recent research on soil remediation is moving toward integrated plant– microbe systems and site-specific decision frameworks rather than one technology being applied everywhere [14].

Another important direction is better life-cycle thinking. A technology should be judged not only by how much pollution it removes from one stream, but also by its energy demand, water consumption, secondary waste, maintenance needs, worker safety, cost, and long-term reliability. This broader assessment can prevent a narrow 'removal efficiency' metric from hiding environmental trade-offs.

X. CONCLUSION

Land and air pollution are connected through common sources and through the movement of contaminants between environmental compartments. Combustion, transport, industry, agriculture, mining, construction, and waste management can all contribute to both atmospheric and land-based pollution. The resulting pollutants can travel through air, soil, water, food chains, and direct human contact, making the boundary between 'air pollution' and 'land pollution' much less clear than it first appears.

Engineering control is most effective when it starts upstream. Cleaner production, source reduction, efficient resource use, and proper waste segregation should be preferred wherever technically possible. Recovery and reuse can reduce the amount requiring treatment. For remaining emissions, devices such as ESPs, fabric filters, scrubbers, catalytic systems, and combustion controls can reduce air pollutants. For land and waste, engineered containment, leachate and gas management, bioremediation, phytoremediation, stabilization, and other site-specific methods can reduce exposure and mobility.

The most important principle is simple: pollution should not merely be moved from one place to another. A successful intervention should reduce pollutant generation or prevent exposure, and monitoring should demonstrate that the risk has actually fallen. Combining engineering design, reliable measurement, appropriate standards, life-cycle thinking, public participation, and long-term verification provides a stronger and more realistic pathway toward cleaner air, healthier land, and sustainable development.

REFERENCES

[1] World Health Organization, WHO Global Air Quality Guidelines: Particulate Matter ($PM_{2\cdot5}$ and PM_{10}), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. Geneva, Switzerland: WHO, 2021.

[2] World Health Organization, “Ambient (outdoor) air pollution,” Fact sheet, Oct. 24, 2024.

[3] G.-P. Bălă, R.-M. Râjnoveanu, E. Tudorache, R. Motișan, and C. Oancea, “Air pollution exposure—the (in)visible risk factor for respiratory diseases,” Environmental Science and Pollution Research, vol. 28, pp. 19615–19628, 2021, doi: 10.1007/s11356- 021-13208-x.

[4] S. Koushal, D. Arya, S. Anbarasan, D. Haloi, R. M, T. Rahman, V. Singh, and N. V. G. Deekshithulu, “Soil Pollution: Sources, Effects, and Mitigation Strategies,” Asian Journal of Soil Science and Plant Nutrition, vol. 11, no. 1, pp. 280–290, 2025, doi: 10.9734/ajsspn/2025/v11i1480.

[5] R. Bhattacharyya et al., “Soil Degradation in India: Challenges and Potential Solutions,” Sustainability, vol. 7, no. 4, pp. 3528– 3570, 2015, doi: 10.3390/su7043528.

[6] World Health Organization, “WHO Global Air Quality Guidelines: Questions and Answers,” WHO, 2021.

[7] Central Pollution Control Board, “National Ambient Air Quality Standards,” Government of India, 2009, and associated ambient-air monitoring guidance.

[8] Central Pollution Control Board, “Salient Features of Solid Waste Management Rules, 2016,” Government of India.

[9] Central Pollution Control Board, “Guidelines for Disposal of Legacy Waste,” Government of India, 2019.

[10] World Health Organization, “Air Quality Standards database,” 3rd ed., updated Jan. 20, 2026.

[11] United Nations Environment Programme, Global Environment Outlook 7: A Future We Choose, UNEP, 2025/2026.

[12] M. Zhao, P. Xue, J. Liu, J. Liao, and J. Guo, “A review of removing SO_2 and NO_x by wet scrubbing,” Sustainable Energy Technologies and Assessments, vol. 47, art. 101451, 2021, doi: 10.1016/j.seta.2021.101451.

[13] A. Perez-Vazquez, P. Barciela, and M. A. Prieto, “In Situ and Ex Situ Bioremediation of Different Persistent Soil Pollutants as Agroecology Tool,” Processes, vol. 12, no. 10, art. 2223, 2024, doi: 10.3390/pr12102223.

[14] Y. Chernysh, V. Chubur, I. Ablieieva, P. Skvortsova, O. Yakhnenko, M. Skydanenko, L. Plyatsuk, and H. Roubík, “Soil Contamination by Heavy Metals and Radionuclides and Related Bioremediation Techniques: A Review,” Soil Systems, vol. 8, no. 2, art. 36, 2024, doi: 10.3390/soilsystems8020036.

[15] A. Jaworek and K. Adamiak, “Recent progress in research on electrostatic precipitation (invited paper),” Journal of Electrostatics, vol. 137, art. 104064, 2025, doi: 10.1016/j.elstat.2025.104064.

[16] F. B. Elehinafe, E. A. Aondoakaa, A. F. Akinyemi, O. Agboola, and O. B. Okedere, “Separation processes for the treatment of industrial flue gases—Effective methods for global industrial air pollution control,” Heliyon, vol. 10, no. 11, art. e32428, 2024, doi: 10.1016/j.heliyon.2024.e32428.

[17] U.S. Environmental Protection Agency, Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup, EPA, 2001.