



International Journal on Eternal Wisdom and Contemporary Science

ISSN (Online): 3107-8184
Volume 3 • Issue 1 • June 2026 • pp 221-233

Air Pollution and its Possible Impact on *Pranayama* Practice

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Abstract:

Air pollution has become a major global health concern, significantly affecting respiratory, cardiovascular, and neurophysiological functioning. At the same time, *Pranayama*, the yogic discipline of regulated breathing, is widely recognized for its therapeutic benefits, including improved lung function, autonomic balance, stress reduction, and enhanced mental well-being. However, *Pranayama* is inherently dependent on the quality of inhaled air, making polluted environments a critical challenge to its safe and effective practice. This paper examines the impact of air pollution—particularly particulate matter (PM_{2.5} and PM₁₀) and gaseous pollutants such as ozone and nitrogen oxides—on *Pranayama* from both biomedical and yogic perspectives. Drawing upon classical yogic texts, including the *Yoga Sūtra* and *Hatha Yoga Pradīpikā*, along with contemporary scientific evidence, the study highlights how polluted air can compromise lung function, increase toxin intake during deep inhalation, disrupt autonomic regulation, and reduce the intended psychophysiological benefits of *Pranayama*. The paper also discusses traditional yogic recommendations for an optimal practice environment and proposes practical adaptations for modern urban settings, such as indoor practice and air purification. The study emphasizes that access to clean air is fundamental for the safe and effective practice of *Pranayama* and overall human well-being.

Keywords: Air pollution, Particulate matter (PM), *Pranayama*

INTRODUCTION

Air pollution, the insidious contamination of the atmospheric environment, has emerged as a global crisis, threatening human health, ecosystems, and the very fabric of our planet. While its presence has been acknowledged for centuries, the scale and complexity of modern air pollution have reached alarming levels, demanding urgent and comprehensive action. WHO

data shows that almost all of the global population (99%) breathe air that exceeds WHO guideline limits and contains high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. According to the World Health Organization, the recommended safe limit for PM_{2.5} is 5 µg/m³ annual mean and 15 µg/m³ for 24-hour exposure, while PM₁₀ should not exceed 15 µg/m³ annually and 45 µg/m³ daily. However, in many urban regions, Air Quality Index (AQI) levels frequently exceed 150–300 (unhealthy to hazardous range), significantly increasing the risk of respiratory and cardiovascular morbidity. From a *Pranayama* perspective, such elevated AQI levels are particularly concerning because deep inhalation increases the deposition of fine particulate matter in alveolar regions. Air pollution is not a singular entity but rather a complex mixture of gaseous and particulate contaminants.

These pollutants can be broadly categorized as:

1. **Particulate Matter (PM):** Microscopic solid and liquid particles suspended in the air. Some particles are big or dark enough to be visible with the unaided eye, like smoke, soot, dust, or soil. Others are so tiny that only an electron microscope can identify them. Particles includes- PM₁₀ (particles with a diameter of 10 micrometers or less) and PM_{2.5} (particles with a diameter of 2.5 micrometers or less). These particles are of particular concern due to their ability to penetrate deep into the respiratory system. Sources include combustion processes, industrial emissions, and natural dust storms.
2. **Gaseous Pollutants:** These include:
 - **Ozone (O₃):** Ground-level ozone, a secondary pollutant formed through the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight.
 - **Nitrogen Oxides (NO_x):** Primarily nitrogen dioxide (NO₂), emitted from combustion sources, especially vehicle exhaust and power plants.
 - **Sulfur Dioxide (SO₂):** Released from burning fossil fuels, particularly coal, and industrial processes.
 - **Carbon Monoxide (CO):** A product of incomplete combustion, mainly from vehicles.
 - **Volatile Organic Compounds (VOCs):** Organic chemicals that evaporate easily at room temperature, emitted from various sources, including paints, solvents, and industrial processes.

The Sources of Contamination

The sources of air pollution are diverse and interconnected, reflecting the complexities of modern society. The contributors include:

- **Transportation:** The rapid proliferation of vehicles, particularly those powered by fossil fuels, has made transportation a major source of NO_x, PM, and VOCs.

- **Industrial Activities:** Industrial processes, including manufacturing, power generation, and mining, release a wide range of pollutants, including SO₂, PM, and heavy metals.
- **Residential Combustion:** Burning solid fuels, such as wood and coal, for heating and cooking, especially in developing countries, contributes significantly to PM and CO emissions.
- **Agricultural Practices:** Agricultural activities, including livestock farming and the use of fertilizers, release ammonia and other pollutants.
- **Natural Sources:** Natural events, such as volcanic eruptions, wildfires, and dust storms, can also contribute to air pollution.

The Devastating Impacts

The consequences of air pollution are far-reaching, affecting human health, ecosystems, and the climate.

- **Human Health:** Air pollution is a major risk factor for a wide range of health problems, including respiratory diseases, cardiovascular diseases, lung cancer, and premature mortality. PM_{2.5}, in particular, can penetrate deep into the lungs and even enter the bloodstream, causing systemic inflammation and damage.
- **Ecosystem Impacts:** Air pollutants can damage vegetation, acidify soils and water bodies, and disrupt ecosystem processes. Ozone, for example, can reduce crop yields and damage forests.
- **Climate Change:** Some air pollutants, such as black carbon and methane, are also potent greenhouse gases, contributing to climate change. Air pollution and climate change are thus inextricably linked, creating a complex and challenging problem.

OBJECTIVE OF THE STUDY

The primary objective of this paper is to critically examine the impact of air pollution on the safety, efficacy, and physiological outcomes of *Pranayama* practice. It aims to integrate classical yogic perspectives with contemporary biomedical evidence to understand how exposure to pollutants such as PM_{2.5}, PM₁₀, ozone, and nitrogen oxides alters respiratory, autonomic, and neurophysiological responses during *Pranayama*. Additionally, the study seeks to propose practical guidelines for safe *Pranayama* practice in polluted environments.

PRANAYAMA

Pranayama, the yogic practice of breath control, extends far beyond simple respiration. It is a sophisticated system designed to regulate *prana*, the vital life force, through conscious manipulation of the breath. *Pranayama* and psychophysiological processes were explained in

a number of ancient yoga literature. The sage Patanjali explained in the "*Yoga Sutra*" that "the mind obtains or develops the ability, expertise, or potential for true concentration through the techniques and processes of *Pranayama*" (Vivekananda et al., 2019). Swami Svatmaram clarified in the *Hatha Yoga Pradipika* that "the mind is unsteady when the breath wanders." However, a tranquil breath will also result in a steady mind (Muktibodhananda Saraswati et al., 2016). This ancient practice, embedded within the eight limbs of *yoga*, has garnered increasing scientific attention for its multifaceted benefits on physical and mental health (Jayawardena et al., 2020). Following a review of different *Pranayama*, a team of researchers found that *Pranayama* may modulate ventricular performance by increasing parasympathetic activity and decreasing sympathetic activity, strengthen cardiorespiratory coupling, improve baroreflex sensitivity, and have a unique effect on the brain stem cardiorespiratory center. They also found that dynamic and smooth both nostril breathing may balance both hemispheres, while left uni nostril breathing is linked to a sympathetic response by activating the right hemisphere while right uni nostril breathing is linked to a parasympathetic response by activating the left hemisphere (Nivethitha et al., 2016).

Some of the evidence based benefits of *Pranayama* are as follows:

Regulation of the Autonomic Nervous System (ANS):

Pranayama techniques can shift the balance between the sympathetic (fight-or-flight) and parasympathetic (rest-and-digest) branches of the ANS. Slow, deep breathing activates the parasympathetic nervous system, promoting relaxation and reducing stress (Jerath et al., 2006).

Improved Respiratory Function:

- *Pranayama* strengthens the respiratory muscles, increases lung capacity, and enhances oxygenation (Das et al., 2022).
- *Pranayama* is beneficial for individuals with respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD) (Das et al., 2022).
- It improves lung function, reduces breathlessness, and enhances exercise tolerance (Karthik, 2014).
- Regular practice can strengthen respiratory muscles and increase vital capacity (Beutler et al., 2016).

Cardiovascular Effects:

- *Pranayama* can lower heart rate, blood pressure, and improve heart rate variability, indicating enhanced cardiovascular health (Sharpe et al., 2021).
- It can lower blood pressure, reduce heart rate, and improve heart rate variability, reducing the risk of cardiovascular disease (Saoji et al., 2019).
- It promotes relaxation and reduces sympathetic nervous system activity, which can contribute to hypertension (Upadhyay et al., 2023).

Neurophysiological Changes:

- Studies have shown that *Pranayama* can influence brain activity, increasing alpha wave production (associated with relaxation) and altering neurotransmitter levels (Streeter et al., 2012).
- Studies suggest that *Pranayama* can enhance cognitive function, including attention, memory, and executive function (Kanchibhotla et al., 2022).
- It may also improve brain oxygenation and promote neuroplasticity (Streeter et al., 2012).

Stress Reduction and Mental Well-being:

- *Pranayama* is a powerful tool for managing stress, anxiety, and depression (Jagadeesan et al., 2022).
- It promotes relaxation, reduces cortisol levels, and enhances emotional regulation (Chakrabarty et al., 2016).
- Some of the studies have demonstrated its effectiveness in alleviating symptoms of generalized anxiety disorder and post-traumatic stress disorder (Seppälä et al., 2014).

Improved Sleep Quality:

- *Pranayama* can promote relaxation and reduce anxiety, leading to improved sleep quality (Gundogdu et al., 2023).
- It can be particularly helpful for individuals with insomnia (Paul et al., 2022).

Immune System Modulation:

- Some studies indicate that *Pranayama* practices can influence immune function, potentially enhancing the body's ability to fight off infections (Trivedi & Saboo, 2021).
- The reduction of stress hormones like cortisol contributes to a healthier immune response (Zope & Zope, 2013).

CHALLENGES POSED BY AIR POLLUTION IN *PRANAYAMA* PRACTICE

Compromised Lung Function:

Air pollutants like PM_{2.5} and ozone can inflame and irritate the respiratory system, reducing lung capacity and making deep breathing difficult. This directly hinders the effectiveness of *Pranayama*. Long-term exposure to air pollution can contribute to the development of chronic lung diseases like COPD and lung cancer (Andersen et al., 2011). Existing respiratory conditions are exacerbated by polluted air that may reduce the efficiency of oxygen uptake and carbon dioxide removal, which can be particularly problematic during *Pranayama* practices that emphasize deep breathing.

Weaken Immune Systems:

Air pollution can weaken the immune system, making individuals more susceptible to respiratory infections like bronchitis and pneumonia (NIH, 2022). Within lung-associated lymph nodes, inhaled particles from environmental contaminants build up in macrophages over years, impairing immune surveillance through direct impacts on lymphoid architecture and immune cell function (Nat Med, 2022). Though *Pranayama* practice helps in enhancing immunity (Trivedi & Saboo, 2021) but unfavourable air quality may interfere with the smooth flow of breath required for *Pranayama*.

Increased Toxin Intake:

Pranayama involves deep inhalation, which, in polluted environments, means a higher intake of harmful toxins. Pollutants like PM_{2.5}, ozone, and nitrogen dioxide irritate the delicate lining of the airways, causing inflammation (CARB, 2020). This makes deep, controlled breathing difficult and uncomfortable. This can negate the purifying benefits of *Pranayama* and potentially harm the body.

Irritation and Discomfort:

Exposure to pollutants can stimulate the production of mucus in the respiratory tract. This excess mucus can obstruct the airways, making it harder to breathe deeply and fully (Eckhardt & Wu, 2021). Air pollutants can irritate the sensitive nerve endings in the nasal passages and throat, causing a burning or itching sensation. This can cause coughing, wheezing, and throat irritation, disrupting the smooth and controlled breathing required for *Pranayama*.

Impact on Nervous System:

Air pollution can contribute to stress and anxiety, which can interfere with the calming effects of *Pranayama*. The body's stress response can lead to shallow, rapid breathing, which is the opposite of the slow, deep breathing required for *Pranayama* (Chu B et. al., 2025). *Pranayama* aims to balance the autonomic nervous system, but air pollution can disrupt this balance by overstimulating the sympathetic nervous system (fight-or-flight response). In essence, air pollution creates a hostile environment for *Pranayama* practice, making it difficult to achieve the intended benefits and potentially causing further irritation and discomfort.

PHYSIOLOGICAL MECHANISMS UNDERLYING THE IMPACT OF AIR POLLUTION

Air pollution affects *Pranayama* practice through several interconnected physiological pathways:

Oxidative Stress and Inflammation:

Fine particulate matter (PM_{2.5}) generates reactive oxygen species (ROS), leading to oxidative stress and inflammation in lung tissues. This damages epithelial cells and reduces pulmonary

efficiency (Kelly & Fussell, 2015; Schraufnagel et al., 2019). During *Pranayama*, increased tidal volume enhances pollutant penetration, thereby amplifying oxidative damage (Shukla et al., 2025).

Impairment of Lung Function:

Pollutants cause bronchoconstriction, airway inflammation, and reduced lung compliance. This directly interferes with slow and deep breathing techniques essential for *Pranayama*, such as diaphragmatic breathing and *kumbhaka* (breath retention) (Brunekreef & Holgate, 2002; Guarnieri & Balmes, 2014; Pope & Dockery, 2006).

Autonomic Nervous System Dysregulation:

Exposure to pollutants has been linked with increased sympathetic activation and reduced parasympathetic tone. This contradicts the fundamental aim of *Pranayama*, which is to enhance vagal tone and induce relaxation (Brook et al., 2010; Delfino et al., 2008).

Neuroinflammation and Brain Effects:

Ultrafine particles may cross the blood-brain barrier, contributing to neuroinflammation. This may reduce cognitive clarity and meditative stability, which are essential outcomes of advanced *Pranayama* practice (Chen et al., 2017; Maher et al., 2016).

OPTIMAL ENVIRONMENT FOR PRACTICING PRANAYAMA

Establishing a conducive environment is crucial for effective *Pranayama* practice. The *Hatha Yoga Pradipika* delineates specific characteristics of an ideal setting, emphasizing seclusion, cleanliness, and safety (Swami Niranjananand Saraswati, 2012; Muktibodhananda Saraswati et al., 2016). The following key attributes are outlined:

Secluded and Secure: The practice area should be free from disturbances and potential hazards, such as rocks, fire, or water. It is recommended to select a location that is tranquil and spiritually uplifting.

Cleanliness and Protection: The space, ideally a hermitage or dedicated room, should be meticulously clean and may traditionally be plastered with cow dung to maintain hygiene. It should be safeguarded from insects and animals, with a small door and adequate protection against drafts.

Appropriate Structural Features: The practice area should not be excessively elevated or low-lying. Traditional texts suggest constructing a platform with a thatched roof, a water well, and a surrounding wall to ensure functionality and safety.

Conducive Ambiance: The overall environment should promote mental tranquility and be conducive to spiritual practices.

ADAPTATION OF *PRANAYAMA* PRACTICE IN MODERN POLLUTED ENVIRONMENTS

Although traditional yogic texts recommend secluded, clean, and natural surroundings for *Pranayama* practice, achieving such ideal conditions is often difficult in contemporary urban settings. Therefore, it becomes essential to adopt practical adaptations to ensure both safety and effectiveness. The following strategies may be considered:

Avoidance of Highly Polluted Outdoor Environments

- Practitioners should avoid performing *Pranayama* in areas with high vehicular traffic, industrial emissions, or visible dust and smoke.
- Polluted environments increase the inhalation of harmful particulate matter, which may negate the therapeutic benefits of *Pranayama*.
- Selecting relatively cleaner environments such as parks, green spaces, or less congested areas can significantly reduce exposure.

Preference for Indoor Practice with Air Quality Control

- Indoor practice is recommended, especially when outdoor air quality is poor.
- The use of HEPA-based air purifiers can effectively reduce indoor particulate matter and improve breathing safety.
- Proper ventilation should be maintained, ensuring that indoor air is fresh but not contaminated by outdoor pollutants.

Use of Air-Purifying Plants

- Incorporating indoor plants known for their air-purifying properties can help improve air quality.
- Commonly recommended plants include:
 - *Chlorophytum comosum* (Spider Plant) (Giese et al., 1994)
 - *Sansevieria trifasciata* (Snake Plant) (Kumar et al., 2023)
 - *Nephrolepis exaltata* (Boston Fern) (Kumar et al., 2023)
- While plants alone may not completely eliminate pollutants, they contribute to a healthier micro-environment and enhance psychological well-being.

Selection of Appropriate Time for Practice

- Timing plays a crucial role in minimizing pollution exposure.
- Early morning hours (preferably before peak traffic) are generally associated with lower pollution levels.

- Post-rain conditions are also favorable, as rainfall helps settle airborne particulate matter.
- Avoid practice during peak traffic hours and late afternoons when pollution levels are typically higher.

AQI-Based Decision Making for Practice

- Monitoring the Air Quality Index (AQI) (Decherney, S., Petruzzello, M., 2026) is essential for informed decision-making regarding *Pranayama* practice.
- The following guidelines may be adopted:
 - AQI 0–50 (Good):
 - Air quality is considered safe.
 - Outdoor *Pranayama* can be practiced without restrictions.
 - AQI 51–100 (Moderate):
 - Acceptable air quality with minor concerns for sensitive individuals.
 - Outdoor practice may be continued with caution.
 - AQI 101–150 (Unhealthy for Sensitive Groups):
 - Individuals with respiratory conditions should avoid outdoor practice.
 - Indoor *Pranayama* is recommended.
 - AQI >150 (Unhealthy to Hazardous):
 - Outdoor *Pranayama* should be strictly avoided.
 - Practice should be limited to indoor environments with air purification.

Integration of Yogic Awareness with Environmental Awareness

- Practitioners should cultivate awareness not only of breath (*prana*) but also of the quality of air being inhaled.
- This reflects a harmonious integration of traditional yogic wisdom with modern environmental health considerations.
- Adapting practice in response to environmental conditions ensures that *Pranayama* remains a safe and beneficial discipline.

Thus, while ideal yogic conditions may not always be attainable, mindful adaptations grounded in both traditional wisdom and scientific understanding can help sustain the efficacy and safety of *Pranayama* practice in contemporary environments.

CONCLUSION

In conclusion, air pollution presents a significant obstacle to the practice of *Pranayama*, a discipline fundamentally reliant on clean and controlled respiration. The detrimental effects of pollutants, such as particulate matter and ozone, directly compromise lung function, increase

toxin intake, and irritate the respiratory system, undermining the intended benefits of *Pranayama*. For individuals with pre-existing respiratory conditions, the risks are amplified, potentially transforming a practice intended for health into a source of harm. However, the challenges posed by air pollution do not render *Pranayama* entirely inaccessible. By adopting mindful modifications, practitioners can mitigate the risks and continue to reap the benefits of controlled breathing. Practicing indoors with air purifiers, choosing optimal times with lower pollution levels, and focusing on gentle techniques are crucial adaptations. *Nadi Shodhana*, with its emphasis on balancing the nervous system and clearing respiratory pathways, can be particularly beneficial in polluted environments. It is paramount to recognize that *Pranayama* is not a shield against air pollution. Rather, it is a practice that must be adapted to the environmental realities. Prioritizing personal safety by staying informed about air quality, consulting healthcare professionals when necessary, and advocating for cleaner air are integral to ensuring that *Pranayama* remains a tool for well-being, rather than a source of further health complications. Ultimately, the pursuit of clean air is not just an environmental imperative, but a fundamental prerequisite for the safe and effective practice of *Pranayama*, and for overall human health.

Brief Profile of the Author:

Dr. Komal is an Assistant Professor at the School of Yogic Science, S-VYASA University, Bengaluru, with expertise in Yoga, Indian philosophy, Vedic wellness, and holistic health education. She holds a Ph.D. in Yogic Science and has qualified UGC NET-JRF along with Yoga Certification Board Level-3 certification as a Yoga Teacher and Evaluator. Her academic and professional journey reflects a blend of teaching, research, administration, and international training experience.

She previously served as Director of Training and Development at BICAS, Kingdom of Bahrain, where she conducted Yoga Teacher Training programs and wellness seminars for diverse communities. Dr. Komal has published several research papers on yoga, psychological wellbeing, spirituality, and Vedic education in reputed journals and is actively involved in interdisciplinary research projects related to yoga therapy and holistic healing.

Apart from academics, she has represented and coached teams at national and international yoga championships, earning multiple medals and recognitions. Her work focuses on integrating ancient Vedic wisdom with scientific approaches to wellness, inspiring students and communities toward balanced and conscious living

Statements and Declaration: I, Dr. Komal, hereby declare that this manuscript is my original work and does not infringe on any rights of third parties. All sources have been duly acknowledged and cited. The author used ChatGPT (OpenAI) for linguistic editing and fine-tuning of the manuscript. This work has not been previously published in whole or in part. No financial support was received for the work within this article.

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