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Editorial

Invisible Threats in Plain Sight: Construction-Related Air Pollution and the Fragility of IVF Laboratory Performance

"When Urban Growth Meets Embryo Sensitivity: Aligning Infrastructure, Policy, and Reproductive Precision"

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Abstract

In vitro fertilization (IVF) laboratories maintain strict control over temperature, gas composition, humidity, and particulate load to protect gametes and early embryos. In contrast, construction-related air pollution remains an under recognized and inconsistently managed risk. Hospital expansion and nearby construction can introduce fine and ultrafine particulate matter (PM2.5 and PM10), volatile organic compounds (VOCs), heavy metals, and microbial aerosols into laboratory environments through ventilation systems, structural gaps, and routine personnel movement.

Preimplantation embryos have limited antioxidant defenses and immature detoxification pathways, making them particularly vulnerable to environmental perturbations. Epidemiologic studies increasingly associate ambient air pollution with adverse IVF outcomes, including reduced fertilization, blastocyst development, implantation, and live birth rates, although exposure assessment varies. Current regulatory frameworks rely on occupational exposure limits developed for adults and do not account for embryo-specific sensitivity.

Construction-related exposures are often prolonged and subtle. Mitigation strategies such as high-efficiency particulate air (HEPA) filtration, VOC adsorption, positive-pressure laboratory design, sealed zoning, and continuous air quality monitoring may help reduce unexplained variability in IVF performance and better align laboratory practice with the biological demands of early human development.

Keywords: Air Pollution, Birth Rate, Fertilization in Vitro, Particulate Matter

Editorial

Few areas of clinical medicine demand the level of environmental precision required in assisted reproduction. In vitro fertilization (IVF) laboratories are designed to maintain narrow tolerances for temperature, gas composition, humidity, and particulate load, based on the recognition that even modest deviations can influence embryo development. Considerable attention is devoted to these parameters. Yet one increasingly common environmental factor construction-related air pollution often remains outside formal laboratory quality frameworks.

Urban academic hospitals and medical centers are in a near-continuous state of expansion and renovation. IVF laboratories may operate adjacent to demolition, structural modification, or prolonged construction activity. These processes generate complex airborne mixtures that include fine and ultrafine particulate matter (PM2.5 and PM10), volatile organic compounds, heavy metals, and microbial bioaerosols. Although embryology laboratories are engineered as controlled environments, they are not biologically isolated. Ventilation systems, pressure differentials, structural microgaps, and routine personnel movement create pathways through which external contaminants can enter.

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The biological vulnerability of gametes and preimplantation embryos renders such exposures particularly consequential. Early embryonic cells have limited antioxidant capacity and immature detoxification mechanisms. A growing epidemiologic literature links ambient air pollution with adverse reproductive outcomes. Elevated PM2.5 prior to oocyte retrieval has been associated with reduced live birth rates following frozen embryo transfer cycles (1). Systematic reviews further show negative associations between ambient pollutants and live birth or intrauterine pregnancy rates in IVF patients (2). Poor air quality during oocyte collection and early culture correlates with reduced clinical pregnancy and implantation rates (3, 4).

Construction-related exposure is notable not only for its potential magnitude, but for its subtlety. Construction projects often span months or years, during which laboratory performance may shift gradually. Changes in fertilization rates, blastocyst yield, or implantation efficiency are frequently attributed to patient characteristics, stimulation protocols, or technical variation, while environmental contributors remain unrecognized. In this setting, construction-related air pollution can function as an invisible confounder, influencing both clinical outcomes and research reproducibility.

These observations also expose a regulatory gap. In pharmaceutical and biologics manufacturing, cleanroom classifications and particulate thresholds are strictly defined and continuously enforced. IVF laboratories, despite handling biologically sensitive material at critical stages of human development, often rely on environmental standards derived from occupational exposure limits intended for adult workers. Such limits were not designed to protect embryos undergoing rapid cellular division and epigenetic reprogramming.

Patients undergoing IVF reasonably assume that laboratory environments are optimized and actively safeguarded against foreseeable risks. Nearby construction is foreseeable, as are its effects on air quality. Yet environmental risk assessments related to construction activity are not consistently required, and air quality monitoring is often intermittent or reactive. In many laboratories, environmental stability is assumed rather than measured.

Professional societies in reproductive medicine are well positioned to address this gap. Evidence-based guidance on particulate and volatile organic compounds (VOCs) thresholds relevant to embryology laboratories could help standardize practice. Accreditation processes might also incorporate environmental risk assessment during periods of nearby construction. Continuous air quality monitoring, when integrated with laboratory performance metrics, allows environmental conditions to be evaluated objectively rather than inferred.

Mitigation strategies are readily available. High-efficiency particulate air (HEPA) filtration, activated carbon VOC scrubbing, positive-pressure laboratory design, and sealed zoning are widely used in other sensitive manufacturing environments. Retrospective studies suggest improved air filtration correlates with higher fertilization, blastocyst development, implantation, and pregnancy outcomes (5). Despite this, implementation remains inconsistent, particularly during high-risk periods such as prolonged construction.

Beyond immediate cycle outcomes, potential longer-term implications merit consideration. The preimplantation period involves extensive epigenetic remodeling. Although direct longitudinal data linking construction-related exposures to long-term offspring outcomes are lacking, evidence from prenatal air pollution research supports biological plausibility. From a precautionary standpoint, minimizing avoidable environmental exposures during early embryogenesis is a defensible approach.

As healthcare systems continue to evolve, construction-related environmental disruption will become increasingly common. Reproductive medicine has traditionally addressed laboratory problems reactively, after performance declines are observed. A shift toward proactive environmental governance incorporating routine surveillance, risk assessment, and mitigation may help stabilize outcomes and reduce unexplained variability.

Technological advances in embryo imaging, AI-assisted selection, and genetic testing have transformed IVF practice. However, no degree of downstream sophistication can compensate for instability in the embryonic environment itself. Construction-related air pollution is not merely an operational inconvenience; it is a measurable and potentially modifiable determinant of laboratory performance. Recognizing and addressing this risk affirms scientific rigor and aligns laboratory practice with the biological vulnerability of early human development.

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Conflicts of Interest

The author has no conflicts of interest to declare.

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