



Review Article

Association of Environmental Pollution and Infertility – A Mini-Review

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Received: 29 March 2025
Accepted: 17 June 2025
Published: 02 August 2025

DOI
[10.25259/FSR_15_2025](https://doi.org/10.25259/FSR_15_2025)

Quick Response Code:



ABSTRACT

Environmental pollution has emerged as a significant global challenge, with detrimental effects on human health, ecosystems, and biodiversity. One of the overlooked consequences of environmental pollution is its adverse impact on reproductive health, contributing to the increasing prevalence of infertility, which affects approximately 12.6% of the global population. Pollution from industrialisation, urbanisation, waste disposal, and pesticide use introduces toxic chemicals, heavy metals, endocrine disruptors, and other pollutants into the air, water, and soil. These pollutants accumulate in the environment and food chains, affecting human fertility outcomes. Multiple studies have highlighted the detrimental effects of environmental pollution on reproductive health, including irregular menstrual cycles, reduced sperm quality, ovarian dysfunction, and increased rates of miscarriage and genetic abnormalities. The pathophysiology behind this includes oxidative stress, endocrine disruption, and direct damage to gametes, affecting both males and females. Exposure to pollutants such as carbon monoxide, sulphur dioxide, nitrogen oxides, heavy metals like mercury and cadmium, and endocrine-disrupting chemicals like bisphenol A and phthalates can disrupt the hypothalamic-pituitary-gonadal axis, leading to impaired gametogenesis and fertility. Furthermore, pollution contributes to long-term chronic health issues, including low-grade inflammation and hormonal imbalances. As evidence of the growing concern, the World Health Organisation has acknowledged the impact of air pollution on fertility, particularly in low- and middle-income countries. Given the widespread nature of this issue, it is crucial to raise awareness, conduct further research, and implement policies aimed at reducing environmental pollution to protect reproductive health and ensure the well-being of future generations.

Keywords: Endocrine disruptors, Environmental pollution, Heavy metals, Infertility, Oxidative stress, Toxic chemicals

INTRODUCTION

Environmental pollution has become a global burden over the last decades.^[1] It affects human health and the ecosystem, as well as biodiversity. On the other hand, infertility has become a high prevalence, affecting about 12.6% of period prevalence according to a recent meta-analysis.^[2] Infertility means the inability to conceive despite unprotected sexual intercourse over a 12-month duration.^[3-5]

Reproductive health, mainly fertility, has been affected by environmental pollution. A result of containment release to the air, water and soil due to pollution resulted in disruption in the humoral function of the body and, on some occasions, the direct impact on gametes. This has a significant effect on both males and females concerning fertility outcomes.

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Industrialisation, urbanisation, waste disposal, and pesticide practices significantly contribute to pollution. It has led to the release of toxic chemicals, heavy metals, toxins to endocrine factors, plastics, and pesticides into the environment. These harmful agents are available in the environment and accumulate in the food chains, water sources, and the air we breathe.

Around the globe, multiple studies have proved that these cause irregularities in menstruation, ovum quality and quantity, sperm quality, function and number. With various pathways, pollution has led to infertility. Some studies have shown that this is a reason for recurrent miscarriages and genetic abnormalities in the foetus.

This review is an effort to raise awareness of the relationship between environmental pollution and reproductive outcomes and highlight the importance of preventing pollution as a part of protecting reproductive health. This will emphasise the importance of more studies to assess this complex relationship between environmental pollution and reproductive health in view of the protection of future generations.

WHAT IS ENVIRONMENTAL POLLUTION?

Environmental pollution is introducing various substances to the environment that affect air, water, soil and ecosystems, which harmfully affect the environment, destroying its well-being. It mainly happens due to human activities.

Air pollution – Releasing harmful gases into the air by emissions from vehicles, power plants, and factories releases gases like carbon monoxide (CO), sulphur dioxide (SO₂), and nitrogen oxides (NO₂), which mainly cause significant harm. Not only that, but multiple particulate matters (PMs) can also be found in polluted air. These can cause health problems and atmospheric changes.

Water pollution – happens when water sources like lakes, oceans, rivers, etc. get contaminated with chemicals, waste products and plastics from various sources such as agriculture, factories and sewage processes. It not only affects humans, but also the water creatures, and other animals will be affected too.

Soil pollution – As a result of environmental pollution, hazardous chemicals, pesticides, heavy metals, and waste material might accumulate in the water sources, plants, and food from soil, which has a significant impact on health and well-being.

Light pollution also plays a significant role in environmental pollution with industrialisation. This also has a substantial impact on the health and quality of life of humans, as well as animals and wildlife.

Effects of Electromagnetic Wave Radiation With the development of technology, the usage of mobiles, wireless devices and other devices with electromagnetic devices came into use, and it has become a popular trend and affordable to the people. However, evidence is emerging to highlight the negative effects on health, particularly on fertility.^[6]

PATHOPHYSIOLOGY – INFERTILITY AND ENVIRONMENTAL POLLUTION

Air pollution, CO, SO₂, NO₂, ozone and particulate materials will lead to oxidative stress, inflammation and endocrine disruption.

Gases and PM will cause an increase in the production of reactive oxygen species (ROS). These damage gametes (ova/sperm) and affect endocrine signalling molecules. Gases like NO₂ and CO will adversely affect the hypothalamic-pituitary-ovarian axis.

This leads to dysregulated menstruation and spermatogenesis. It will clinically manifest as menstrual irregularity, ovarian dysfunction, oligozoospermia, asthenozoospermia or teratozoospermia.^[7] Also, ROS can directly damage DNA and its replication process.

Prolonged exposure to air pollution can cause low-grade chronic inflammation, which might affect gametogenesis, implantation and fertilisation. It will also increase recurrent implantation failure, recurrent miscarriages, and preterm births.

Water pollution with heavy metals like mercury, lead, cadmium (Cd), pesticides, and endocrine-disrupting chemicals (EDCs) can alter reproductive function.^[8] Phthalates and bisphenol A are EDCs affecting oestrogen, progesterone and testosterone signalling, the main reproductive hormones. Patients will have menstrual irregularities. Polycystic ovarian syndrome in women and reduced sperm production, low motility and morphology in men. Heavy metal can directly affect the ovaries and testicles, leading to infertility.^[9]

The same with soil pollution. It leads to the accumulation of chemical solutions and heavy metals like lead in the food chain, primarily via pesticide usage and industrial waste. This can affect reproductive functions and hormone regulation, causing poor sperm quality and number and ovarian dysfunction.

Long-term exposure to high levels of noise gives rise to chronic psychological stress, ultimately causing endocrine disruption. High cortisol levels due to psychological stress can inhibit the gonadotropin-releasing hormone, the key regulatory hormone of homeostasis of the hypothalamic-pituitary-gonadal axis. Ultimately, patients will have irregular menstruation. Low sperm count leads to the inability to conceive. Also, noise pollution will lead to sleep disturbances.

Healthy sleep is mandatory to maintain a healthy hormone balance in the body. Hence, poor sleep will disrupt hormonal regulations and lead to poor reproductive outcomes.

As evident so far, mainly from animal studies, electromagnetic radiation can lead to DNA damage, specifically in gametes, and can increase oxidative stress by increasing free radicals. Hence, it will reduce fertility potential mainly in males.^[10]

Environmental pollution not only affects reproductive health but also affects the overall health of individuals' physical, psychological, and material quality of life in different ways. The main goal for better fertility outcomes and good public health is to prevent long-term exposure to multiple agents in polluted air, water, soil, and noise.

DISCUSSION

The World Health Organisation (WHO 2025) stated that 99% of the global population breathes air that is over the limits of WHO guidelines, which means it contains pollutants. Further, they have highlighted that low- and middle-income countries have the highest exposure to polluted air.^[11] Even the WHO has recognised that environmental pollution, notably air pollution, has a health impact on male and female reproductive ability, specifically on gamete quality.^[12]

Zhou and colleagues studied the effect of pollution on mice. They proved that ovarian dysfunction with exposure to PM in the polluted air over a 4-month duration not only increases oxidative stress but also reduces folliculogenesis and increases cell apoptosis.^[13] It is well-proven in animal studies that increased oxidative stress leads to telomere dysfunction and DNA damage, resulting in miscarriage and infertility.^[14] Furthermore, animal studies showed that exposure to polluted air causes reduced antral follicle count (AFC).^[15] Multiple epidemiological studies on air pollution exposure to female fertility showed a negative correlation between air pollution and AFC and ovarian reserve.^[16] Katarzyna and colleagues published research on air pollution and ovarian reserve parameters, concluding that women exposed to PM in the air have decreased serum AFC and anti-Mullerian hormone levels. They also showed that SO₂ had a negative correlation with AFC.^[17]

As a result of soil and water pollution, heavy metals accumulate in the water and food chains, such as arsenic (As). It is proven that some rice has a high level of As. Animal studies demonstrated that it causes increased ROS and sex hormone changes, such as reduction in oestradiol (E₂), Follicle-stimulating hormone (FSH), and Luteinizing hormone (LH) levels and reduced ovarian weight by follicular atresia and uterine weight by thinning the endometrial glandular structure.^[18,19] The study done by Jie Lin and the team showed that urinary As has a significant correlation

with infertility as well as age factor^[8] among American women between the ages of 20 and 44.

Lead is another health-endangering heavy metal mostly found in water that affects fertility by reducing the E₂ level and reducing the mature follicles, which has been proven among Toronto women with long-term exposure to Pb.^[20] Serum level of Pb had a significant negative correlation with mature oocyte count, implantation, clinical pregnancy rate and sustained pregnancy among women with unexplained infertility.^[21] Epidemiological studies done in Taiwan and China concluded that blood Pb concentration is significantly higher among infertile women than among pregnant women.^[22]

Among Pd, As, Zn, Cd and copper, Cd mainly affects male infertility. Urinary Cd level has a positive correlation with abnormal sperm morphology.^[23]

Exposure to radiofrequency electromagnetic fields (RF-EMF) can increase DNA fragmentation and high oxidative stress, leading to male infertility via reduced sperm count, motility, and low morphologically normal sperm.^[6,24] Also, it can affect hormone homeostasis, leading to disruption of hormone regulation, which reduces reproductive potential in both males and females by affecting testicular and ovarian activity.^[24-26] This RF-EMF exposure can reduce ovarian and testicular weight as well. To prevent these negative effects, people should be encouraged to limit exposure to those devices, maintain a distance from such devices, maintain a 'digital detox' zone within the households and maintain a healthy lifestyle overall.

CONCLUSION

Environmental pollution happens through air, soil, water, noise or light pollution by industrialisation, improper garbage disposal, waste from agricultural industries and many other ways. It affects humans and the ecosystem of the world. This has become a global crisis for decades. A polluted environment affects the physical, psychological and material quality of life, including reproductive potential. It affects fertility mainly via endocrine disruption, induction of oxidative stress and epigenetic modification. Hence, preventing environmental pollution is crucial for the sustainability of the human species and the ecosystem in the future.

Author contribution: KPM: Concept, literature review, manuscript editing and review; PD: Design, literature review, manuscript preparation, editing and review; WGMT: Concept, design, literature review, manuscript preparation, submission, editing and review.

Ethical approval: Institutional Review Board approval is not required.
Declaration of patients consent: Patient's consent is not required as there are no patients in this study.

Financial support and sponsorship: Nil.

Conflicts of interest: There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation: The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Tissera WGM, Mallawaarachchi KP, Desai P. Association of Environmental Pollution and Infertility – A Mini-Review. *Fertil Sci Res.* 2025;12:25. doi: 10.25259/FSR_15_2025