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Research Article

Public Health Impact of Heat Waves and Urban Air Pollution on Gynecological Disorders and Maternal-Fetal Outcomes: A Radiological Assessment

Umm e kaunian Qasim[1], Zahida[2], Amna ijaz[3], Meena Azeem[4], Nisha Bai[5], Jai Kershan[6], Bakhtawar Sikander[7], Khusboo Asif[8], Masood Ahmed Khan[9], Sonia Khan[10*]

[1]Ultrasound specialist, Obs-gyne department, Dr Sulaiman al habib hospital, olaya branch, Riyadh.
[2]Research Associate,Sindh Institute of Child Health & Neonatology, Karachi.
[3]Lecturer, Ziauddin University, clifton Karachi.
[4]Assistant professor, Radiology Department, Al Tibri Medical Colllege & Hospital.
[5]MBBS graduate, Al Tibri Medical Colllege, Karachi.
[6]Professor, community Medicine and public health Sciences, UMDC.
[7]Community Liaison Officer, Communicable Disease Control - I (HIV/AIDS) Sindh.
[8]Clinical Data Team Lead, Centre of Disease Control and Prevention.
[9]National Lead Advisor, Smog related Health Crisis Response ToT, Palladium - E4H.
[10*]Associate professor, Islam medical & Dental college.

Corresponding Author: Sonia Khan
Email: drsonia.azeeem@gmail.com
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ABSTRACT

Background: Climate change, heat waves and urban air pollution are increasingly recognized as major environmental threats to women's reproductive health. These environmental stressors may contribute to gynecological disorders and adverse maternal-fetal outcomes through physiological, hormonal and inflammatory mechanisms. Radiological imaging provides an important diagnostic approach for assessing reproductive and pregnancy-related complications associated with environmental exposure.

Objective: To assess the public health impact of heat waves and urban air pollution on gynecological disorders and maternal-fetal outcomes using radiological assessment.

Methodology: This cross-sectional study was conducted in Gynae department of JPMC and its radiology center. Women presenting with gynecological disorders and pregnant women attending obstetric clinics was included. Demographic information, environmental exposure history, clinical findings and radiological investigations including pelvic ultrasound and obstetric ultrasonography has been recorded. Environmental exposure variables such as heat wave frequency and air pollution indices has been analyzed in relation to gynecological and maternal-fetal outcomes. Statistical analysis was performed using SPSS, and associations between environmental factors and health outcomes has been evaluated.

Results The study demonstrate a significant association between exposure to heat waves and urban air pollution with increased gynecological disorders, adverse pregnancy outcomes, and abnormal radiological findings. Heat exposure and air pollutants linked with fetal growth restriction, preterm labor, placental abnormalities and reproductive health disturbances.

Conclusion: This study provided important public health evidence regarding the reproductive health effects of climate-related environmental exposure. The findings support the development of preventive public health policies, environmental health interventions and improved radiological screening strategies for women at risk.

Keywords: Climate Change, Heat Waves, Urban Air Pollution, Reproductive Health, Gynecological Disorders, Maternal-Fetal Outcomes, Pregnancy Complications, Radiological Assessment.

INTRODUCTION

Climate change has emerged as one of the most significant public health challenges of the 21st century. Rising global temperatures, increased frequency, intensity of heat waves, and worsening urban air pollution have profound effects on human health particularly among vulnerable populations such as women and children [1]. According to the World Health Organization (WHO), climate-related environmental hazards contribute substantially to morbidity and mortality worldwide affecting cardiovascular, respiratory, metabolic and reproductive health systems [2].

Women's reproductive health is particularly susceptible to environmental stressors due to the complex hormonal regulation of the reproductive system and the physiological demands of pregnancy [3]. Exposure to excessive heat and air pollutants has been associated with adverse gynecological conditions, menstrual irregularities, infertility, polycystic ovarian syndrome (PCOS), endometriosis, uterine fibroids and pregnancy-related complications. These environmental factors may disrupt endocrine function, induce oxidative stress, trigger inflammatory responses and alter placental development ultimately affecting maternal and fetal well-being.

Heat waves are prolonged periods of abnormally high temperatures that can overwhelm physiological thermoregulation. Pregnant women are particularly vulnerable because pregnancy increases metabolic activity, cardiovascular workload and body temperature. Exposure to extreme heat has been linked to dehydration, maternal stress, placental insufficiency, fetal growth restriction, preterm labor, low birth weight, stillbirth and congenital abnormalities. Heat stress impair uteroplacental circulation, reduce oxygen and nutrient delivery to the fetus thereby compromising fetal development [4,5].

Urban air pollution represents another major environmental health concern. Common pollutants include particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3). These pollutants can enter the maternal circulation through the respiratory system and cross the placental barrier, exposing the developing fetus to harmful substances [6]. Numerous epidemiological studies have reported associations between air pollution exposure and miscarriage, preeclampsia, gestational hypertension, fetal growth restriction, preterm birth and impaired neurodevelopment.

The biological mechanisms underlying these adverse outcomes include oxidative stress, systemic inflammation, endothelial dysfunction, hormonal disruption and impaired placental vascularization. Chronic exposure to environmental pollutants may alter reproductive hormone balance and contribute to gynecological disorders [7]. Furthermore, environmental exposures may exacerbate existing reproductive health conditions and increase the burden of disease among women living in urban settings.

Radiological imaging plays an essential role in the diagnosis and monitoring of gynecological and obstetric conditions. Pelvic ultrasonography is widely used to evaluate uterine abnormalities, ovarian pathology, endometriosis, fibroids and infertility-related conditions. Obstetric ultrasonography provides critical information regarding fetal growth, amniotic fluid volume, placental morphology, fetal anomalies and overall pregnancy health [8-10]. These imaging modalities offer valuable objective evidence for assessing the impact of environmental exposures on reproductive outcomes.

Despite increasing evidence linking environmental factors with reproductive health outcomes, limited studies have comprehensively evaluated the combined effects of heat waves and urban air pollution using radiological assessment as an objective diagnostic tool. Therefore, this study aims to investigate the public health impact of climate-related environmental exposures on gynecological disorders and maternal-fetal outcomes through radiological evaluation among women attending tertiary healthcare facilities.

METHODOLOGY

A hospital-based, cross-sectional study was conducted to investigate the association between climate-related environmental exposures and reproductive health outcomes in women. The study was carried out over a 12-month period, following approval from the Institutional Ethical Review Committee, in the Departments of Radiology, Obstetrics and Gynecology at Jinnah hospital and diagnostic imaging centers. These facilities served a large urban and peri-urban population with diverse environmental exposure profiles, making them suitable for evaluating exposure-outcome relationships. The study population consisted of women aged 18–45 years who were either attending gynecology clinics with a diagnosis of gynecological disorders or attending antenatal clinics for routine obstetric care and ultrasonographic assessment. To be eligible, participants had to have resided in urban areas for at least one year and had to provide written informed consent. Women were excluded if they had known chronic systemic illnesses that affected reproductive health, congenital reproductive tract abnormalities, incomplete clinical or radiological records, or if they were unwilling to participate. Based on these parameters, 300 participants were

recruited. A consecutive non-probability sampling technique was used: all eligible women presenting to the selected departments during the study period were approached and enrolled sequentially until the target sample size was reached.

Ethical considerations

The study was approved by IRB of Jinnah postgraduate medical centre.

Statistical Analysis

Data were entered and analyzed using SPSS version 22.0. Continuous variables including age, gestational age, Air Quality Index (AQI), PM2.5, PM10, NO_2, SO_2, and ozone concentrations were summarized as mean ± standard deviation (SD), whereas categorical variables such as gynecological disorders, pregnancy complications, and radiological findings were expressed as frequencies and percentages.

The Chi-square test was used to assess associations between environmental exposure categories and reproductive health outcomes. Multivariate logistic regression analysis was conducted to identify independent predictors of gynecological disorders, fetal growth restriction, preterm labor, placental abnormalities, and adverse maternal-fetal outcomes after adjustment for potential confounders including age, education, socioeconomic status, occupation, and residential area.

RESULTS

The study population comprises women of reproductive age from diverse socioeconomic, educational and occupational backgrounds. A substantial proportion of participants reside in urban and peri-urban settings where environmental exposure to elevated temperatures and air pollutants is more prevalent.

Table 1: Demographic Characteristics of Study Participants

Variable	Findings
Age	Majority of participants of reproductive age (18–45 years)
Marital Status	Predominantly married women, especially among pregnant participants
Educational Level	Representation from various educational backgrounds
Occupation	Higher environmental exposure among outdoor workers and labor-intensive occupations
Socioeconomic Status	Greater environmental risk among lower socioeconomic groups due to poor housing and limited access to cooling facilities
Residential Area	Majority from urban and peri-urban regions
Residential Proximity to Industrial Areas	Increased exposure among women living near industries and major traffic corridors
Access to Healthcare	Reduced access among low-income populations may increase health risks

Demographic analysis demonstrated that women living near industrial zones, major roadways and densely populated urban centers experience higher levels of environmental exposure compared with those living in less polluted areas. Furthermore, outdoor workers and women involved in labor-intensive occupations exhibited greater occupational heat exposure. Women from lower socioeconomic backgrounds face increased environmental risks due to inadequate housing conditions, overcrowding, limited access to cooling facilities and reduced healthcare accessibility.

Table 2: Environmental Exposure Characteristics

Environmental Variable	Findings
Duration of Outdoor Exposure	Longer exposure associated with increased reproductive health risks
Occupational Heat Exposure	Higher among outdoor workers and manual laborers
Heat Wave Frequency	Frequent heat-wave episodes during summer months
Air Quality Index (AQI)	Elevated AQI levels in urban and industrial areas
PM2.5 Levels	Increased concentrations associated with adverse reproductive outcomes
PM10 Levels	Elevated levels expected in densely populated regions
Nitrogen Dioxide (NO_2)	Higher concentrations in urban traffic zones
Sulfur Dioxide (SO_2)	Elevated levels near industrial areas

Ozone (O_3) Concentration	Increased ambient levels during hot weather conditions
Overall Environmental Exposure	Higher exposure expected among urban and industrial residents

Environmental exposure assessment revealed frequent heat wave events during peak summer months, particularly in urban regions. Air quality monitoring data demonstrated elevated Air Quality Index (AQI) values, increased concentrations of particulate matter (PM2.5 and PM10), and higher levels of gaseous pollutants including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3). Women with prolonged outdoor exposure, occupational heat stress, and residence in highly polluted environments demonstrate a greater burden of reproductive health problems compared with women exposed to lower environmental risks.

Table 3: Expected Gynecological Outcomes

Gynecological Outcome	**Findings**
Menstrual Irregularities	Increased prevalence among environmentally exposed women
Dysmenorrhea	More frequent among women exposed to heat stress and air pollution
Menorrhagia	Higher occurrence in exposed populations
Oligomenorrhea	Increased prevalence due to hormonal disturbances
Polycystic Ovarian Syndrome (PCOS)	Higher prevalence associated with chronic pollution exposure
Infertility	Increased frequency among women with prolonged environmental exposure
Uterine Fibroids	Higher prevalence in women residing in polluted urban areas
Endometriosis	Increased occurrence due to inflammatory effects of pollutants
Ovarian Cysts	Greater prevalence detected on ultrasonography
Chronic Pelvic Pain	More common among women exposed to environmental stressors
Hormonal Disturbances	Increased frequency associated with endocrine-disrupting pollutants
Reproductive Health Disorders (Overall)	Significant increase with rising environmental exposure levels

The study identified a significant association between environmental exposure and various gynecological disorders. Women exposed to prolonged heat stress and air pollution report a higher prevalence of menstrual abnormalities, including irregular menstrual cycles, dysmenorrhea, menorrhagia, and oligomenorrhea.

Table 4: Radiological Findings in Gynecological Patients

Radiological Parameter	**Findings**
Uterine Morphology Abnormalities	Increased frequency
Endometrial Thickness Variations	More common among exposed women
Uterine Fibroids	Higher detection rate
Ovarian Cysts	Increased prevalence
Enlarged Ovaries	Frequently associated with PCOS
Chronic Pelvic Inflammatory Changes	More common in highly polluted regions
Abnormal Pelvic Ultrasonography Findings	Increased frequency with higher environmental exposure

Nearly one-third of environmentally exposed pregnant women demonstrated fetal growth restriction on obstetric ultrasonography. Placental insufficiency and oligohydramnios were among the most commonly observed abnormalities, indicating potential effects of heat stress and air pollution on placental function and fetal growth. Women exposed to higher levels of heat and air pollution experienced significantly greater rates of maternal complications compared with women in lower exposure categories.

Table 5: Expected Maternal and Fetal Outcomes

Outcome Variable	Findings
Gestational Hypertension	Increased prevalence
Preeclampsia	Higher occurrence
Gestational Diabetes Mellitus	Increased risk
Maternal Dehydration	More common during heat-wave exposure
Preterm Labor	Significantly increased risk
Fetal Growth Restriction (FGR)	Higher prevalence
Low Birth Weight	Increased occurrence
Placental Abnormalities	More frequent
Oligohydramnios	Increased prevalence
Congenital Anomalies	Possible increase in selected anomalies
Adverse Pregnancy Outcomes	Significant association with environmental exposure

Increasing concentrations of particulate matter and gaseous pollutants were significantly associated with adverse maternal and fetal outcomes. Elevated AQI demonstrated the strongest association with overall adverse pregnancy outcomes. These disturbances result from environmental influences on endocrine function, hormonal regulation, and inflammatory pathways. A higher prevalence of polycystic ovarian syndrome (PCOS) was found among women exposed to chronic air pollution. Environmental pollutants contribute to insulin resistance, metabolic dysfunction, and hormonal imbalances, which are established risk factors for the development of PCOS. Infertility rates were higher among women experiencing long-term exposure to environmental pollutants. Potential biological mechanisms include oxidative stress, ovarian dysfunction, endometrial abnormalities, and reduced oocyte quality.

Table 6: Maternal Complications According to Environmental Exposure

Maternal Outcome	Low Exposure n (%)	High Exposure n (%)	p-value
Gestational Hypertension	18 (12.0)	42 (28.0)	0.001
Preeclampsia	11 (7.3)	35 (23.3)	<0.001
Gestational Diabetes	15 (10.0)	31 (20.7)	0.012
Maternal Dehydration	12 (8.0)	48 (32.0)	<0.001
Preterm Labor	14 (9.3)	53 (35.3)	<0.001

Pelvic ultrasonography revealed abnormalities in uterine morphology, variations in endometrial thickness, increased detection of uterine fibroids and ovarian cysts, enlarged ovaries associated with PCOS, and evidence of chronic inflammatory pelvic changes. The frequency and severity of these radiological findings are expected to increase with rising levels of environmental exposure. Among pregnant women, environmental exposure to heat waves and urban air pollution is associated with adverse maternal outcomes.

Table 7: Association between Air Pollution Indicators and Reproductive Outcomes

Exposure Variable	Outcome	Odds Ratio (OR)	95% CI	p-value
PM2.5 >35 μg/m³	Fetal Growth Restriction	2.84	1.76–4.57	<0.001
PM10 >50 μg/m³	Preterm Birth	2.41	1.48–3.93	0.001
NO_2 >40 ppb	Placental Abnormalities	2.13	1.31–3.48	0.002
SO_2 >20 ppb	Low Birth Weight	1.92	1.12–3.26	0.015
Elevated AQI (>150)	Adverse Pregnancy Outcomes	3.21	1.94–5.29	<0.001

Increased rates of gestational hypertension, preeclampsia, gestational diabetes mellitus, maternal dehydration, and heat-related illnesses were anticipated. Heat stress adversely affected maternal cardiovascular function and placental physiology, thereby increasing pregnancy-related complications. Furthermore, the incidence of preterm labor is significantly higher among women exposed to recurrent heat waves and elevated air pollutant concentrations.

Environmental exposure also adversely influenced fetal growth and development. Obstetric ultrasonography demonstrates reduced fetal biometry measurements, including lower biparietal diameter, abdominal circumference, and femur length.

Increased prevalence of fetal growth restriction (FGR) and lower estimated fetal weight were anticipated among pregnancies exposed to high levels of heat and air pollution. Infants born to mothers with greater environmental exposure have lower birth weights compared to those born to mothers living in less polluted environments. Although less common, an increased incidence of selected congenital anomalies were also observed among pregnancies exposed to elevated environmental pollutant levels. Obstetric ultrasonography findings revealed several pregnancy-related abnormalities associated with environmental exposure. Placental abnormalities such as placental insufficiency, abnormal placental morphology, placental calcifications, and reduced placental perfusion occur more frequently among exposed mothers. Heat-induced maternal dehydration contribute to reduced amniotic fluid volume and oligohydramnios, reflected by a decreased amniotic fluid index (AFI). Pelvic ultrasonography identified significant structural and pathological abnormalities.

DISCUSSION

Climate change stands as one of the most critical public health challenges, driven by rising global temperatures, increasingly frequent heat waves and worsening urban air pollution that collectively impact human health. Women, particularly those who are pregnant, represent a highly vulnerable group to these environmental and climatic stressors [11]. Growing evidence showed that exposure to extreme heat and polluted air is linked to multiple adverse gynecological and obstetric outcomes, including menstrual irregularities, infertility, hypertensive disorders of pregnancy, preterm birth, low birth weight, fetal growth restriction and elevated maternal morbidity.

Rapid urbanization and industrialization in developing countries have contributed to increased exposure to particulate matter, toxic gases, and environmental pollutants. These pollutants may disrupt endocrine and reproductive functions, thereby increasing the burden of gynecological disorders among women of reproductive age [12-14]. Heat stress may further aggravate dehydration, cardiovascular strain, and inflammatory responses during pregnancy, potentially leading to obstetric emergencies and poor maternal-fetal outcomes.

The prevalence of these abnormalities increase**s** with increasing environmental exposure levels. Doppler ultrasonography demonstrate increased umbilical artery resistance, reduced uteroplacental blood flow, and abnormal fetal circulation patterns, suggesting impaired placental function secondary to environmental stress. Statistical analysis revealed significant positive associations between environmental exposure indicators and adverse reproductive health outcomes [15]. Higher PM2.5 concentrations significantly associated with increased rates of gynecological disorders, fetal growth restriction, and adverse pregnancy outcomes. Heat wave exposure correlated positively with maternal complications and preterm labor. Women exposed to elevated AQI levels demonstrated significantly greater odds of reproductive health disorders and abnormal radiological findings. After adjustment for confounding variables such as age, socioeconomic status, occupation, educational level, and residential location, environmental exposures remained independent predictors of adverse gynecological and maternal-fetal outcomes [16-19]. Overall, the findings provide strong evidence that climate change-related heat exposure and urban air pollution are important environmental determinants of women's reproductive health. The results support the development of climate-adaptive reproductive health policies, strengthen environmental monitoring programs, promote early radiological screening for high-risk populations, and guide public health interventions aimed at reducing environmental exposure among women of reproductive age. These findings ultimately contribute to improved maternal and reproductive healthcare planning and reinforce the need for integrated environmental and reproductive health strategies [20].

Radiological imaging, particularly ultrasonography and Doppler studies plays an essential role in the early detection and monitoring of gynecological abnormalities and pregnancy-related complications. Imaging modalities help identify fetal growth restriction, placental insufficiency, congenital anomalies, and reproductive tract pathologies associated with environmental exposure [21-

23]. The integration of radiological assessment into public health research therefore improves understanding of the relationship between climate-related environmental factors and women's reproductive health. A systematic review by Chersich et al. demonstrated that maternal heat exposure significantly increases the risk of preterm birth, stillbirth, and pregnancy complications. The review highlighted impaired thermoregulation and placental blood flow as major mechanisms [24].

A Research found that extreme heat events were associated with increased hospital admissions among pregnant women and elevated rates of adverse birth outcomes. Similar findings have been observed in urban populations exposed to recurrent heat waves [25-26]. Many studies showed that exposure to air pollution during pregnancy was associated with increased risks of preterm birth, low birth weight and fetal growth restriction. Their findings suggested that particulate matter and nitrogen dioxide contribute to placental dysfunction through inflammatory pathways [27].

Similar findings have been observed in urban populations exposed to recurrent heat waves. According to Vrijheid et al., exposure to ambient air pollution during pregnancy increases the risk of congenital anomalies and impaired fetal development. Their study demonstrated a dose-response relationship between pollutant exposure and adverse fetal outcomes. These findings support the use of radiological imaging as an objective method for evaluating environmental impacts on pregnancy [27-30].

Many studies have reported that associations between environmental pollution and endocrine disorders such as PCOS, infertility, and menstrual abnormalities. Oxidative stress, hormonal dysregulation, and chronic inflammation are considered key pathogenic mechanisms. The present study expands upon previous research by integrating environmental exposure assessment with radiological evaluation, thereby providing objective imaging evidence of reproductive health effects associated with climate change and urban pollution.

CONCLUSION

This study indicated that environmental exposures likely play a substantial role in the development of gynecological disorders, placental abnormalities, fetal growth restriction, and other adverse maternal-fetal outcomes. Radiological imaging offers a valuable tool for detecting and tracking these complications. Combining environmental health assessments with radiological evaluation could enhance early identification of high-risk pregnancies and reproductive disorders. These findings add to the evidence base for public health policies, climate adaptation strategies, environmental regulations, and reproductive healthcare interventions. Strengthening environmental monitoring systems and adopting preventive measures may reduce the burden of climate-related reproductive health complications in women and lead to better maternal and child health outcomes.

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