REVIEW ARTICLE

Effects of the Meteorological Phenomena on the Female Reproductive System – A Narrative Review

Sarada Satyamoorthy Garg[1], Rekha Shanmugam[2], Vidhya Venugopal[3]*

[1,2,3]Department of Environmental Health Engineering, Sri Ramachandra Institute of Higher Education and Research, Chennai, Tamil Nadu, India

DOI: 10.55489/njcm.160320254874

ABSTRACT

Introduction: Meteorological conditions affect female reproductive health, although little is known about their biological mechanisms. We undertook a narrative review to fill this gap by analysing published research on how meteorological factors, including extreme temperatures, humidity, precipitation, pressure, and wind/storm, affect women's reproductive health. This review emphasises the significance of environmental factors on reproductive health and guides future research.

Methods: We conducted a thorough literature survey on the effects of meteorological factors; we systematically searched databases such as PubMed, Google Scholar, and Scopus. We scrutinized all the pertinent original articles, book chapters, reports, and news articles, classifying the impacts on gynaecology, obstetrics, and cancer.

Results: Meteorological phenomena are highly sensitive to environmental changes and have an impact on women's gynecological and obstetric health. Our research demonstrates that these meteorological phenomena may lead to gynaecologic effects such as endometriosis and PCOS. Furthermore, it causes hormonal imbalances and potentially disrupts blood flow, which leads to adverse pregnancy conditions such as miscarriages, stillbirths, preterm birth, low birth weight, and other effects like cancer.

Conclusion: Understanding these impacts is critical for developing strategies to mitigate adverse effects on female health, ensuring sustainable protection in the face of changing climatic conditions.

Key words: women reproductive health, climate change, humidity, wind, precipitation, pressure

ARTICLE INFO

Financial Support: None declared

Conflict of Interest: The authors have declared that no conflict of interests exists.

Received: 16-11-2024, **Accepted**: 28-01-2025, **Published**: 01-03-2025

***Correspondence:** Vidhya Venugopal (E-mail: vvidhya@ehe.org.in)

How to cite this article: Garg SS, Shanmugam R, Venugopal V. Effects of the Meteorological Phenomena on the Female Reproductive System – A Narrative Review. Natl J Community Med 2025;16(3):303-314.
DOI: 10.55489/njcm.160320254874

www.njcmindia.com │ pISSN: 0976-3325 │ eISSN: 2229-6816 │ Published by Medsci Publications

INTRODUCTION

The global burden of disease (24%) and approximately 9 million deaths are attributable to environmental factors, including hazardous biological, physical, and chemical factors in the environment.[1,2] The meteorological phenomena are observable weather events, including the studies of temperature, pressure, humidity, and precipitation, wind velocity and direction, and the movement of air currents and clouds leading to heat and cold waves, floods and droughts, cyclones and storms, and wildfires.[3]

Climate change may worsen health in vulnerable groups like women, children, and the elderly.[4] Women have higher workloads, job dangers indoors and outdoors, psychological and emotional stress, and mortality than men, according to the IPCC.[5] Women and girls are last in household food hierarchy and more likely to skip meals, making them more vulnerable to food insecurity.[6] The numerous social, cultural, and economic elements in society harm women's reproductive health throughout time.[7] Changes in temperature, humidity, and other climatic variables may affect population, particularly women and their reproductive health and in 2019, 39.6% (1.5 billion) of all females suffered from gynaecological diseases, including death and disability from uterine fibroids, polycystic ovarian syndrome, endometriosis, genital prolapse, menstrual disorders, and others.[8]

Meteorological conditions mostly affect thermoregulation and the female reproductive system. Oestrogen and progesterone regulate body temperature and autonomic thermoregulation.[9] Progesterone raises body temperature, while oestrogens lower it by improving heat dissipation.[9] Extreme heat can also cause pre-eclampsia, low birth weight, and gestational diabetes in pregnant women, emphasising the need to understand and mitigate meteorological effects on the female reproductive system.[10] Many environmental stressors lead to detrimental alterations in genes, epigenetic or microRNA (tiny molecules which helps to control the cell function), which in turn impact signalling cascades causing imbalance in the production and removal of reactive oxygen species (ROS).[11] DNA damage, P450 enzyme activation, and hormonal alterations can all play a role in compromising placental function.[12] Environmental exposure in early life influences the pattern of immune maturation, as well as the resulting immune response and inflammation.[13]

Epidemiologic research shows that climatic changes affect fertility, prenatal outcomes, mental and sexual health, reproductive rights, and survival. There are few global indicators on women and climate change.[14] This review examines how meteorology may affect women's reproductive health. Understanding these linkages is essential for optimal reproductive outcomes and creating strategies to minimise climatic impacts on female reproductive health and formulate policies to mitigate the effects to protect current and future generations.

METHODOLOGY

To assess the current impact of meteorological phenomena on the female reproductive system, we conducted this narrative review. We conducted a systematic search of the literature in various combinations. We searched the PubMed, Google Scholar, and Scopus databases for relevant articles published in peer-reviewed journals. The search strategy aimed to locate numerous studies that examined the potential impact of weather conditions such as temperature, humidity, and rainfall on female reproductive health, including the regulation of the menstrual cycle.[4,15-17]

The study's inclusion criteria included studies that focused on females of any age group, including girl children, adolescent girls, pregnant women, women of reproductive age, and older women. Inclusion criteria included studies that looked at the effects of weather events like temperature, heat stress, extreme weather, climate change, and other environmental factors. They also included studies that looked at the effects on gynaecological, obstetric, cancer, and reproductive health outcomes that were linked to the specific exposures. These studies include observational studies (cross-sectional, case-control, and cohort studies), clinical trials, and review articles. The study includes articles written in English, studies from 2001 to 2024, and articles from peer-reviewed journals. Articles not published in English meet the exclusion criteria. We excluded the papers if they did not relate meteorological phenomena to the outcomes of the study on female populations.

Extracting and Synthesising Data: We searched the literature on weather and female reproduction based on the finalised search terms. We divided search terms into exposure, result, and population. We found all full-text publications that met the requirements after two independent reviewers examined titles and abstracts. We deleted duplicates and extensively reviewed remaining papers. A standard form was utilised to capture data on study design, demographic characteristics, exposure types, outcomes measured, and key findings. A third reviewer helped us fix data extraction inconsistencies.

Search Terms: The exposure keywords include terms related to weather and climate phenomena, such as "hot temperature," "extreme heat," "heatstroke," "heat index," "summer temperature," "summer weather," "heat wave," "global temperature," "climate change," "global warming," "acclimatisation," "meteorology," "climatology," "biometeorology," "cold temperatures," "extreme cold weather," "vapour pressures," "humidity," "tropical climate," "wind," and "storm." The result keywords focus on a variety of gynaecological and reproductive health issues. These include "female reproduction," "gynaecological effects," "uterine fibroids," "polycystic ovarian syndrome," "endometriosis," "genital prolapse," "premenstrual syndrome," "menstrual disorders," "ovarian cancer," "polycystic ovarian disease," "oxidative stress," "per oxidative DNA damage," "induction of apoptosis," "lipid peroxidation," "fertility," "altered ovulation," "vasomotor," "sleep," "menopause," "menorrhagia," "dysmenorrhea," "ovarian hormone changes," "genitourinary issues," "obstetric effects," "adverse pregnancy outcomes," "low birth weight," "still birth," "intrauterine growth restriction (IUGR)," "preterm," "miscarriage," "abortions," "foetal health," "maternal health," "fertility," "foetal development," "reproductive health," "infant mortality," "oestrogen," "progesterone," and "attributable deaths." The population keywords include terms related to the specific demographic groups of interest, such as "female," "girl children," "women," "adolescent girls," "pregnant women," "reproductive age group women," "young women," "vulnerable population," and "gender." Consequently, we determined the final selection of articles by using the search keywords and searching the reference lists of the retrieved articles for cross-references and related citations from the published literature.

Details of Ethics Clearance: Ethical clearance was obtained from the Sri Ramachandra Institute of Higher Education and Research Institutional Ethics Committee (IEC) (IEC-NI/21/FEB/77/37).

Results and Discussion

It is critical to understand the relationship between meteorological phenomena and women's reproductive health, as environmental conditions have a significant impact on a variety of physiological processes that influence women's reproductive health. Our research underscores the potential for temperature extremes, humidity fluctuations, precipitation patterns, and atmospheric pressure variations to disrupt blood flow and induce hormonal imbalances in women (Table 1).

Thermal Impacts and Humidity on women's reproductive health:

Heat exposures: Exposure to high temperatures causes physiological stress on the human body, which exacerbates the top causes of death globally. People living in low and middle-income countries are more susceptible to the effects of heat exposure, with women among the vulnerable groups (Fig 1). A study found that a 14.7% daily mortality increase occurs in India when temperatures rise to the $>97^{th}$ annual percentile for two consecutive days.[18] There are cascading short-term heat effects, such as heat cramps, heat exhaustion, and heat stroke, as well as vector-borne and other infections. Additionally, socioeconomic factors, such as food and shelter insecurity, access to hygiene, and health care influence health.[19] In tropical areas where women work in heat-stressed environments, the core body temperature can rise by more than 1°C.[19]

Humidity effects: Lee M et al. studied a random sample of 4548 daily reports on health symptoms for the month of October 2018 in Japan. They found that women were more sensitive to weather conditions, especially higher humidity and lower temperatures.[20] Only low absolute humidity increased the risk. Low humidity may lead to an increase in solar radiation. In high humidity, the short-wave reflection of sunlight increases. Also, the skin is more hydrated, reducing dry skin symptoms and radiation exposure to the skin.[21] Females appeared to be more sensitive to these changes.

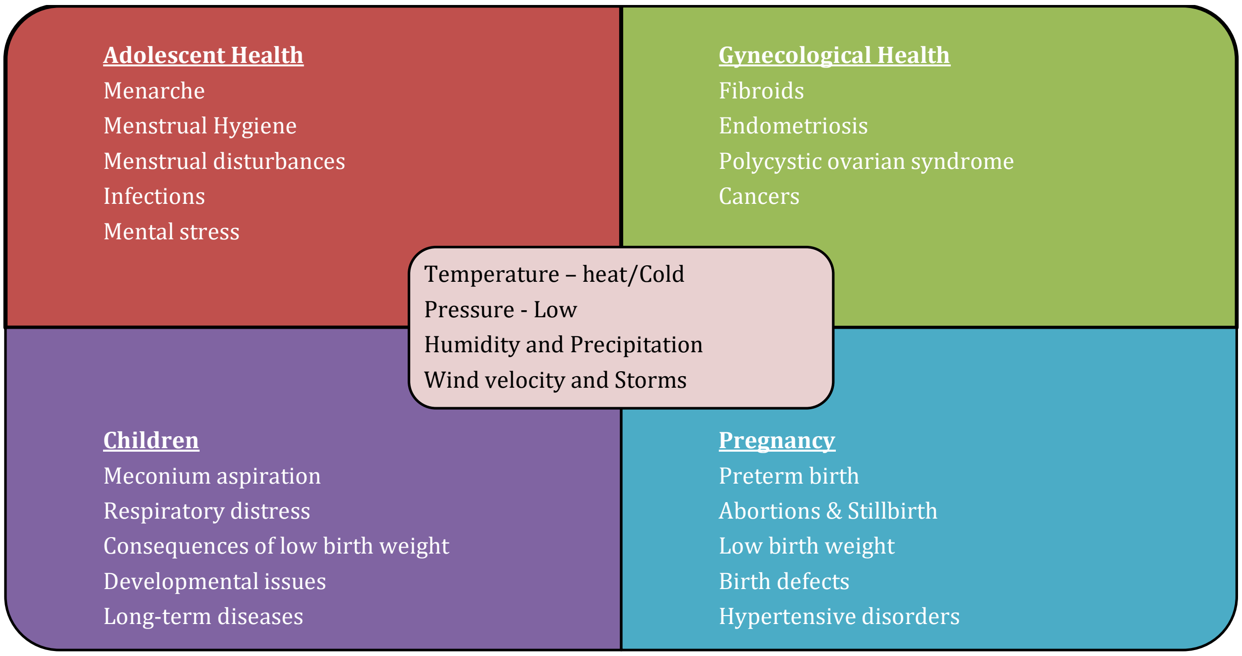

Figure 1: Effects of Meteorological phenomena on reproductive health

Table 1: Summary of literature evidences the impacts on Gynaecological, Obstetric and Carcinogenic effects

	Heat Exposure	Cold Exposure	Pressure Changes (altitude)	Humidity & Precipitation	Winds & Storms
Gynaecological Effects	↑ risk of developing fibroid uterus, endometriosis, polycystic ovarian disease due to ↑ oxidative stress, peroxidative DNA damage, induction of apoptosis, lipid peroxidation	↑weight due to ↓ activity in brown adipose tissue due to ovarian hormone changes which may affect leptin activity	Age of menarche ↑ and that of menopause ↓ due to lower estrogen and progesterone levels	↑exposure to endocrine disrupting chemicals (EDC) present in air, soil and water after precipitation alter hormonal levels leading to menstrual disturbances, fibroids, polycystic ovarian syndrome and ↓fertility	↑exposure to toxins including endocrine disrupting chemicals, along with winds and storms, increased psychological stress can alter menstrual cycles
	↓fertility due to ↓ ovarian reserve, altered ovarian proteome with ↑FSH and follicle size, altered ovulation, altered vaginal chemical and microbial composition and infection	↑ Dysmenorrhea due to disturbed blood circulation and ↑ prostaglandin production		Lack of menstrual hygiene due to insufficient/ unsafe water during droughts & floods can predispose to infections	
	Vasomotor, sleep, psychomotor and other menopausal symptoms seen in large temperature differences between summer and winter, may be due to altered hypothalamic thermoregulatory function			Anemia, diarrhea and skin infections increase after floods due to nutritional deficiencies, inflammation and stress	
Obstetric Effects	↑ risk of abortion, pre term birth, low birth weight due to alteration of blood flow in placenta, ↑maternal body temperature, ↑ cortisol and arginine vasopressin leading to uterine contractions, oxidative stress, inflammation, dehydration & electrolyte imbalances	↑ risk of premature rupture of membranes, preterm birth, stillbirth still birth due to uterine blood vessel constriction and ↑ in blood viscosity, infections	↑risk of preterm delivery and low birth weight due to ↓ placental oxygen delivery to the growing fetus, changes in growth factors and insulin factors causing hypoglycemia	↑risk of unwanted pregnancies, preterm delivery and low birth weight due to nutritional deficits, dehydration and psychological stress as well as inadequate healthcare access	severe stress occurs during storms and can lead to fetal distress, meconium aspiration syndrome and respiratory distress in newborn
	↑ risk of fetal anomalies, neural injuries due to activation of heat-sensitive ion channels in cardiac/neural crest cells, ↑unmet metabolic demand	Congenital heart disease due to ↓ in blood flow and oxygenation to embryo			Toxins in wildfires ↑ fetal defects in the respiratory and nervous system, cleft palate and gastroschises due to DNA damage, oxidative stress and inflammation
Cancers	↑ risk for acute lymphoblastic leukemia in the child due to ↑ambient temperatures at ~8weeks gestation due to altered hematopoiesis (Rogne T, 2023). Basal cell carcinoma incidence is higher with exposure to ultraviolet rays of the sun	The epigenetic program or the cold inducible uncoupling protein (UCP-1) or RNA binding protein can ↑ reactive oxygen species and ↑ predisposition to cancer and mortality	Cellular hypoxia inducible factors altering genes and proteins, ↑angiogenesis and metastasis of cancers	↑solar radiation produces DNA damage. Tropical ozone exposure leading to free radical exposure ↑risk of cancers	Smoke has many carcinogens and winds carrying them to far off places can increase cancer rates.

Gynaecological effects: Danilenko KV has observed a trend towards increased FSH release, larger ovarian follicles, increased ovulation (97% vs. 71%), and a 0.9-day shorter menstrual cycle in the summer.[22] Tatsumi et al. found that the basal body temperature during both the follicular and luteal phases was higher during summer and lower in winter, but not the cycle length.[23] Researchers have found that heat stress alters the ovarian proteome and some pathways in pre-pubertal girls.[24] Heat stress in summer may reduce fertility in the next few weeks.[25] Exposures to heat stress altered the composition of microbes in rabbits' vaginas, which have significantly similar microbes to those in humans.[26] There is a relative abundance of *Actinobacteria, Proteobacteria, Fusobacterium,* and *W5053*, all of which affect reproductive functions.[26] Increases in syringic acid and linolelaidic acid, which are anti-oestrogenic, also affect vaginal ecology's hormone-induced signalling and chemicals altering the hormonal balance.[26] Sanitation facilities could cause genitourinary issues, compounding the problem.[19,27]

As temperatures rise, ozone levels in the atmosphere increase. Ozone levels have been associated with a higher risk of developing uterine lieomyomas, especially in women <35 years and parous women.[28] Studies on animals have demonstrated that temperature changes escalate oxidative stress within the body, potentially impacting physiological functions such as the heart, liver, kidney, brain, and reproduction.[29,30] Oxidative stress can lead to DNA damage, apoptosis, and lipid peroxidation, all of which can affect the growth of endometriosis, polycystic ovarian disease, and uterine fibroids.[31] Thermal strain alters haematological parameters such as mean cell volume and red and white blood cell count.[32] Oxidative stress markers, such as nitric oxide levels, rise in blood.[32]

Obstetric effects: In heat, pregnant women's body temperature control is less effective. Placenta blood flow may change, causing difficulties.[4] Higher temperatures in the first few weeks following conception increase clinically undetected pregnancy loss.[33] First-trimester heat waves may cause small for gestational age newborns or stillbirths.[34,35] A global survey of 14 nations found that preterm and stillbirth rates increased in the week after exposure to high heat and a diurnal variation of less than 16°C, particularly among rural women with low education and wealth.[5] Meta-analyses suggest that preterm and stillbirth risks rose 1.05-fold for 1°C temperature increase.[36,37] Heat acclimatisation or living in hotter areas may have fewer consequences, although most studies demonstrate negative effects.[38] A decrease in body surface area to body mass during pregnancy and foetal growth may increase metabolism, heat stress, and labour. Uterine contractions may elevate cortisol and arginine-vasopressin.[37] Due to electrolyte imbalances, endothelial and oxidative stress, and inflammation, dehydration and reduced foetal blood supply may cause labour.[36] Recent observation cohort evidence shows that working pregnant women in their first and third trimesters exposed to above-threshold limit values had a 3.8-fold and 2.7-fold increased risk of miscarriage and adverse birth outcomes (95% CI: 1.1-13.0 & 1.2-6.3).[39] Due to "energy failure," raising maternal body temperature increases the risk of neonatal brain injury by 2.5-fold. At higher temperatures, the foetal brain cannot satisfy its increased oxygen and substrate demand due to a greater metabolic rate. Heat episodes can cause gestational diabetes and foetal harm.[36] Heart and septal abnormalities increase when cardiac progenitor neural crest cells activate heat-sensitive ion channels (TRPV1 and TRPV4).[37] Heat stress affects antibody and cell-mediated immunity, rendering pregnant women more susceptible to infections.[7] Hot flushes were less common in women in warmer climates like India at menopause and did not vary with season.[40] When summer and winter temperatures differed significantly, women had higher vasomotor symptoms.[41] How external temperature affects menopausal women's sleep cycles and mental health needs further study.[42]

Indirect effects: Food habits may also shift to more dairy and animal foods, replacing whole grains and fiber-rich foods. Diets high in animal proteins and soy are associated with early menarche.[43-46] Chronic malnutrition, not having enough food, and eating a lot of vegetables and flavonoids may, on the other hand, delay puberty because adiposites release low levels of leptin and the hypothalamus takes longer to release gonadotropin-releasing hormone (GnRH). This can affect the hormone cascade.[44,47] Obesity in childhood is associated with earlier puberty.[47]

B. Cold Exposure: Gynaecologic effects: oestrogen secreted by the ovary has multiple roles, including heat dissipation. Progesterone, secreted after ovulation in the second half of the menstrual cycle, plays a role in increasing the body temperature by about 0.5°C. However, researchers have not thoroughly studied how these hormones aid in thermoregulation during cold exposure.[48] Shivering, non-shivering thermogenesis, and cutaneous vasoconstriction all conserve temperature. Non-shivering thermogenesis is heating production in skeletal muscles and brown adipose tissues. In lower mammals, such as rats, estrogen and progesterone influence this adipose tissue. Decreased activity of this tissue has been found in women with PCOD exposed to mild cold, and this is correlated to BMI and waist circumference.[48] A study used Sprague-Dawley rats and found that RFRP-3, a chemical in the brain that controls GnRH release, also changed ovarian steroidogenesis. This led to a polycystic ovary phenotype.[49] Researchers have also found that female rats' uterine epithelial height and shape change a lot when they are exposed to cold.[2] This is likely because the levels of oestrogen and progesterone change. Cold exposure has been associated with increased dysmenorrhea due to disturbed blood circulation as well as increased prostaglandin production.[50] Cold stress can increase endothelin, a strong vasoconstrictor. This can mess up the local micro-vascular circulation in rats' reproductive systems.[51]

Obstetric effects: A population-based study during pregnancy linked coarctation of the aorta to a 1°C drop in cold spells and extreme cold days for live births with at least one week of embryogenesis in the winter.[52] This may be due to uterine vessel constriction and decreased utero-placental blood flow. In China also, extreme cold events during the embryonic period have been associated with congenital heart defects.[53] A retrospective birth data study from 1915–1929 in Uppsala, Sweden, found that the hazard ratio for stillbirth was 1.08 for every 1°C decrease in temperature.[54,55] In China, exposure to extreme cold events one week before delivery also increased the risk of preterm birth and preterm premature rupture of membranes.[56] A systematic review and meta-analysis also concluded that the risk of preterm birth increases with low ambient temperature exposure in late pregnancy.[57]

Carcinogenic effects: Researchers found that females living above 36.5°N in the United States had a 5-7 times greater risk of developing cancer compared to those living below this latitude.[58] Regardless of race or ethnicity, women living in places with lower average annual temperatures in the United States have higher incidence rates of 13 anatomical site-specific cancers, including breast, uterine, and ovarian (but not cervical) cancers.[58] The trend was higher for uterine cancer compared to other cancers. The epigenetic program can be changed by prolonged cold stress, as well as proteins like cold-inducible uncoupling protein (UCP-1), which increases the activity of UCP proteins, or cold-inducible RNA-binding protein. These changes can increase the accumulation of reactive oxygen species, thereby increasing the predisposition to cancer.[59] A study conducted on the correlation between 17 variables and the cancer mortality rate across 188 countries.[59] Researchers found that the cancer mortality rate was lower in countries between 33°N and 23.5°S compared to those with higher latitudes. A higher metabolic rate needed to maintain body temperature in the cold may increase stress and activate sympathetic nervous system, contributing to the higher cancer mortality.[59]

Impacts of Pressure and altitude changes:

High altitude refers to areas that are more than 2500 meters above sea level. With increasing altitude, the temperature, pressure, and humidity decrease, but solar radiation increases. As atmospheric pressure decreases, the partial pressure of oxygen decreases, in turn leading to hypoxia and the consequences on the cardiovascular, respiratory, and reproductive systems. A study in Poland found atmospheric pressure changes were inversely associated with systolic blood pressure in winter and spring.[60]

Gynaecologic effects:- A one-year study in Switzerland found that a higher mean temperature and barometric pressure predicted an increase in pelvic pain, menorrhagia/metrorrhagia.[61] A study among 15,370 girls in Columbia found that girls living in higher altitudes (≥2000 m) had a later age of menarche than girls living at altitudes <1000 m.[45] Studies are not conclusive as to whether exposure to high altitudes during a particular phase of the menstrual cycle can influence the development of acute mountain sickness.[62]

Obstetric effects:- Studies have also found that the average age of menopause is lower among women living at higher altitudes compared to women living at sea level.[63] The reason is not clear, but it may be due to hormonal changes with higher Follicular Stimulating Hormone and lower oestrogen in women at higher altitudes in the peri-menopausal period.[63] It is, however, not known whether short-term exposure to high altitudes also induces an earlier menopause. Research has shown a decrease in both testosterone and progesterone levels in lowlander women who were exposed to high altitude for short periods of time on trekking.[64] Research has reported a difference in oestrogen and progesterone levels during menstrual cycles between women living in high and low altitudes, despite having the same luteal phase and endometrial thickness.[65]

A study in South Carolina, USA, found a weak correlation between preterm labour, precipitation, and pressure change.[66] The European Study of Cohorts for Air Effects, which looked at 13 birth cohorts from 1994 to 2011, found that the risk of giving birth before the due date rose by 1.06 for every 5 mbar rise in the first-trimester atmospheric pressure. Altitude did not affect this risk.[67] A systematic review of 59 studies found that the risk of spontaneous preterm birth and low birth weight increased with altitude.[68] The authors found a 54.7 g decrease in birth weight per 1000 m rise in altitude. Another systematic review of 52 articles found a reduction in mean birth weight of 96.98 g for every 1000 m increase in altitude, but no change in preterm birth rates.[69] This might be because of the drop in air pressure with elevation, less oxygen getting to the growing baby through the placenta, and changes in the baby's growth factors and insulin levels, which lead to low blood sugar in the baby and changes in the placenta's metabolism.[70] However, in highlanders, adaptation reduces the effects by 50%.[70]

Carcinogenic effects: In Ecuador, South America, an epidemiological study compared the prevalence and risk of cancer-related deaths between individuals living at altitudes >2000 meters above sea level and those living at lower altitudes. The higher regions significantly increased the prevalence of all studied cancers, including uterine cancer, and showed significant differences for breast and stomach cancer. The risk of death was 1.13 times higher, except for cervical cancer.[71] People who live at higher elevations have cellular hypoxia-inducible factors that can change genetic transcription, cause post-translational protein changes, boost angiogenesis, and make it easier for metastasis to happen, among other things. Researchers in the United States discovered a decrease in cancer and heart disease mortality at higher altitudes, which they attributed to higher natural background radiation and lower oxygen levels.[72] A review of epidemiological and animal studies also concluded that mortality due to cancer decreases at high altitudes.[73] We need to explain the balance between oxygen-dependent and oxygen-independent mechanisms contributing to this phenomenon. More studies are required in this field.

Impacts of Precipitation, flood and drought changes:

The frequency, intensity, and duration of droughts and floods are increasing as climate change's effects become more apparent. Women are more vulnerable in such scenarios due to changes in nutrition, migration, hygiene, and environmental exposures. They are also vulnerable to physical, sexual, and domestic violence, as well as mood and mental disorders.[4] This could potentially impact their access to safe and potable water.

Gynaecologic effects: Lower temperatures significantly increased menstrual cramps. Girls in the highest quintile of intrauterine exposure to rainy days in the tropics had an earlier age of menarche compared to girls in the lowest quintile in a study of 15,370 girls in Columbia.[45]

Obstetric effects: Dehydration can affect foetal growth, preterm labour, and increase maternal risk for pre-eclampsia and anaemia.[4] Exposure to drought in the first and third trimesters has been associated with odds of a lower birth weight.[74] Pathways that are thought to lead to this outcome are stress, food insecurity, increased infectious diseases, insufficient access to health care, and other environmental stressors.[74] Drought exposure in pregnancy can lead to an increase in the child's body weight and peripheral adiposity. This could be due to the cells' epigenetic accelerated ageing.[75]

Carcinogenic effects: A study in China found that absolute humidity, temperature mean, and diurnal temperature range had a negative correlation with cancer deaths.[21] If the diurnal temperature range was high or low, the risk of death increased.

Direct and indirect effects: Changes in temperature and precipitation also alter the distribution of vector-borne diseases like Zika virus, malaria, or dengue, which can have long-term consequences for mother and foetus malformations and growth.[4] Anaemia, diarrhoea, fever, and skin infections seem to be common among women after floods.[76] Floods may cause anaemia in women due to nutritional deficiencies, waterborne disease-induced inflammation, significantly decreased retinol concentration, or high psychological stress.[77] Women who must evacuate and live in camps have limited access to separate latrines and bathing facilities.[76] Many women reported not having sanitary, hygiene, and delivery kits.[76] This can result in feelings of fear and embarrassment, particularly among young girls.[78] Women have a higher incidence of leucorrhoea and urinary tract infections in addition to pregnancy-related complications during floods.[79] Unavailability of contraceptives may lead to unwanted pregnancies.[78] During these disasters, access to healthcare is difficult, especially reproductive and sexual health care.[76,78,79] In a recent study in Pakistan, the key barrier to seeking healthcare was distance.[76] A large percentage of maternal deaths may occur during transfer to healthcare facilities in rural areas during floods, as noted in Bangladesh.[80]

Floods can increase the exposure to chemicals altering hormonal balance due to flood waters and emissions from industries.[81] Harmful chemicals disrupting agents change the balance of oestrogen and progesterone in the body, mess with microRNA regulation and pathways related to inflammation, and may raise the risk of getting fibroids.[82]

Droughts lead to scarcity of water, and women often need to fetch water from faraway sources. This can lead to musculoskeletal pain and injury. Food insecurity and poor hygiene and sanitation contribute to malnutrition, infections, and health deterioration. Researchers have found that precipitation-based droughts and floods increase the risk of women experiencing both physical and emotional intimate partner violence.[83,84] Reasons for this may include poverty, illiteracy, food insecurity, migration, disempowerment, addictions, and psychological stress.[84,44] Few studies found that environmental changes brought about by these meteorological events could potentially alter the age of menarche through nutrition and exposure to toxins. Growth between the ages of 2 and 7 years seems to play a role in the timing of menarche. Also, the girls who are extremely underweight or overweight are at risk for irregular menstrual cycles and fertility issues.[44] Exposure to endocrine hormone disrupting chemicals as a result of droughts, floods, cyclones, or storms also plays a role in menstrual irregularity, infertility, and pregnancy issues.

Impacts of Winds and Storms:

Changes in wind direction and velocity can have far-reaching effects. Long distances carry pollutants from agriculture, industrial smoke, volcanoes, wildfires, and storms away from their source. Tropical cyclones (typhoons or hurricanes) are among the most destructive weather phenomena.[85] They cause massive destruction of lives and property, with both direct and long-term indirect losses. During runoffs and floods, storms can release chemicals, heavy metals, petroleum hydrocarbons, and infectious agents into the air and water, as well as gaseous toxins from punctured storage tanks. All of these things can affect people's land, drinking water, the ocean, and all living things.[86,87]

Obstetric effects:- Exposure to storms can cause severe stress during pregnancy, stressing the neuroendocrine and immune functions of the foetus.[88] Storm exposure during the first and third trimesters of pregnancy increased the risk for meconium aspiration syndrome and the newborn's need for a ventilator for more than 30 minutes.[88] After ruling out other factors like migration and changes in maternal behaviour and care, the authors thought that stress explains the health outcomes in the newborn.[88] During pregnancy, exposure to wildfires can cause fetal defects such as respiratory and nervous system defects, cleft palates, and gastroschises. Mechanisms may include exposure to PM 2.5, carbon monoxide, and toxicants, as well as mental and psychological stresses, all of which can affect the developing foetus.[89] Particulate matter from forest fires contains polyaromatic hydrocarbons, which can cause DNA damage, reactive oxidative stress, and inflammation.[90] Pregnant women exposed to wildfires are also at greater risk for preterm birth and low birth weight.[91]

Carcinogenic effects: Wildfire smoke is a mixture of carbon dioxide, other greenhouse gases, and hazardous air pollutants such as $PM_{2.5}$, NO_2, ozone, aromatic hydrocarbons, or lead, as well as some carcinogens like formaldehyde or benzene.[92,93] The risk of wildfires is increasing with droughts, heat waves, and high winds.[92] Volatile organic compounds and endocrine hormone disrupting chemicals found in smoke increase cancer risks. An analysis of 2 million people followed up for 20 years in Canada found that wildfire exposure increased the incidence of lung cancers and brain tumours.[94] Researchers in Brazil studied over 1 million cancer deaths and discovered that exposure to wildfires increased the risk of many cancers, such as those of the skin, respiratory and gastrointestinal systems, and reproductive tract, including the testis, prostate, and breast.[56,95] Researchers have also found that female firefighters, exposed to smoke, experience different types of cancers at an earlier age than the general public, such as breast, cervical, and uterine cancers.[96]

Other effects: Smoke carries air pollutants long distances; for instance, stubble burning in Punjab, hundreds of kilometres away, deteriorates Delhi's air quality to extremely poor levels in the winter. Far-off lands experience the effects of wildfires and volcanic eruptions, which release copious amounts of particulate matter and chemicals. Moving air carries pollen and spores, causing allergies and infections elsewhere. In high temperatures, ozone formation increases.

Research gaps, future perspectives and practical implications: Although research indicates that climatic circumstances affect female reproductive health, a considerable gap exists in comprehending the specific biological mechanisms at play. The majority of research concentrates on temperature, with minimal investigation into additional elements like as humidity, precipitation, pressure, and the effects of wind and storms. Moreover, research is often geographically limited, resulting in findings that may not be applicable to varied climates and populations. Future study ought to prioritise longitudinal studies, examine a broader spectrum of meteorological variables, and assess their effects on hormonal, ovarian, and placental functions to enhance the understanding of these environmental influences. Public health campaigns to promote antioxidant-rich diets, stricter industrial emissions and urban pollution regulations, and workplace heat stress mitigation policies like hydration and rest breaks for outdoor women workers are practical solutions. High-risk populations can be screened for oxidative stress indicators to diagnose associated disorders early, and awareness initiatives can teach the women in the public to reduce chemical exposures at home using eco-friendly alternatives. Researching how environmental factors affect genes and ROS production might inform targeted health interventions and legislation. Public health initiatives that prioritize these actionable activities might dramatically reduce oxidative stress-related disorders and enhance health.

Conclusion

It is evident from this research that meteorological factors have a substantial impact on the gynecological and obstetric health of women. This can result in complications such as menstrual irregularities, infertility, pregnancy complications such as abortions, birth defects, preterm births, low birth weight babies, and gynecological malignancies, which can have a cascading effect on infants and families. As well as indirect factors such as pollution, infections, and nutritional deficiencies, these outcomes are influenced by direct environmental exposures, such as heat, cold, and precipitation. Hormonal changes, inflammation, and oxidative stress appear to be primary factors, although the precise mechanisms are still being investigated. In order to confront these obstacles, it is necessary to intensify interdisciplinary endeavors in order to develop more effective interventions and gain a more comprehensive understanding of the health consequences. In order to mitigate the escalating consequences of climate change and guarantee the long-term health of women and their families, it is imperative to implement strategic measures, such as policymaking, public education, disaster prevention, and enhanced healthcare infrastructure.

Acknowledgement: The authors highly acknowledge and thank the Department of Environmental Health Engineering, Sri Ramachandra Institute of Higher Education and Research, Chennai for providing us this platform for carrying out the work. Then the author wants to appreciate the help of Mrs. Subashini. T, Mr. Raja Maarthi for guiding in literature consolidation section.

Contribution to Authorship: Authors contributed to the conception (SG, VV), planning (SG, VV, SR),

carrying out (SG, VV, SR), and writing, editing, finalizing up of the manuscript (SG, VV, SR).

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