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Review Article

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Climate Change and Its Impact on Female Reproductive Health

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Summary

A worldwide occurrence, climate change has profound effects on many facets of human existence, including health. The frequently disregarded relationship between climate change and female reproductive health is the major topic of this review. The reproductive health of women has particular challenges due to climate change, which is also linked to extreme weather events and environmental degradation. Maternal and child health outcomes are jeopardized, access to reproductive healthcare services is restricted, and healthcare infrastructure is disrupted as a result of rising temperatures, changing precipitation patterns, and an increase in the frequency of natural disasters. Furthermore, alterations in environmental factors have the potential to worsen the existing disparities in reproductive health, with a disproportionate impact on marginalized communities. A comprehensive strategy that incorporates gender-sensitive legislation, community resilience-building, and climate change mitigation techniques is needed to address the psychosocial effects of climate change on women. Understanding the intersectionality of vulnerabilities and addressing the particular difficulties experienced by women in various situations are crucial. A comprehensive strategy that takes into account sustainable farming methods, healthcare access, economic empowerment, and nutritional education is needed to address the complex interactions between food security and female fertility behavior. Communities' general growth and well-being can benefit from policies and initiatives that work to enhance both food security and reproductive health. One should keep in mind that this field is complex and constantly changing, and our understanding of these relationships is always expanding. The current review delves into the various ways that climate change affects the health of women through direct and indirect pathways. These include changes in fertility rates, elevated risks of unfavourable pregnancy outcomes, and increased rates of maternal illness and mortality.

Keywords: WHO, climate change, fertility, pollutants, endocrine disruptors.

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Изменение климата и его влияние на репродуктивное здоровье женщин

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Резюме

Изменение климата, происходящее во всем мире, оказывает глубокое воздействие на многие аспекты человеческого существования, включая здоровье. Часто игнорируемая связь между изменением климата и женским репродуктивным здоровьем является основной темой этого обзора. Репродуктивное здоровье женщин подвергается особому риску из-за изменения климата, которое также связано с экстремальными погодными явлениями и ухудшением состояния окружающей среды. Здоровье матери и ребенка находится под угрозой, доступ к услугам по охране репродуктивного здоровья ограничен, а инфраструктура здравоохранения нарушена в результате повышения температур, изменения характера осадков и увеличения частоты стихийных бедствий. Кроме того, изменения экологических факторов могут усугубить существующие различия в уровнях репродуктивного здоровья, что окажет непропорциональное влияние на маргинализированные сообщества. Для решения женских психосоциальных проблем, связанных с изменением климата, необходима комплексная стратегия, включающая в себя законодательство, учитывающее гендерные аспекты, повышение устойчивости сообществ и методы смягчения последствий изменения климата. Понимание взаимосвязей между уязвимостями и помощь в преодолении особых трудностей, с которыми сталкиваются женщины в различных ситуациях, имеют особое значение. Так, для решения сложных зависимостей между продовольственной безопасностью и моделями репродуктивного поведения женщин необходима комплексная стратегия, учитывающая методы устойчивого земледелия, доступ к здравоохранению, расширение экономических прав и возможностей и обучение правильному питанию. Политика и инициативы, направленные на улучшение как продовольственной безопасности, так и репродуктивного здоровья, будут способствовать общему росту и благосостоянию сообществ. Необходимо учитывать сложность и постоянные изменения в этой области, а также постоянное расширение нашего понимания этих взаимосвязей. В настоящем обзоре рассматриваются прямые и косвенные эффекты воздействия изменения климата на здоровье женщин, включая снижение показателей фертильности, повышение рисков неблагоприятных исходов беременности и рост уровней материнской заболеваемости и смертности.

Ключевые слова: ВОЗ, изменение климата, фертильность, загрязняющие вещества, эндокринные разрушители.

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1. Introduction

Climate change is influencing human lives and health in numerous ways. An area's temperature and climate are influenced by the amount and angle of sunshine it receives, which is determined by its distance from the equator where lower temperatures at higher elevations are observed because of the thinning of the atmosphere and the drop in air pressure. Mountains

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and valleys are examples of physical land features that can affect the climate through modifying patterns of precipitation and wind. Human actions, particularly the burning of fossil fuels and deforestation, contribute to climate change and global warming by releasing greenhouse gases into the atmosphere. It threatens the essential components of good health – clean air, safe drinking water, a nutritious food supply, and safe shelter – and has the potential to undermine decades of progress in global health [1]. Human health in general is significantly impacted by climate change, which affects both mental and physical health with a number of societal, environmental, and health-related issues impacted by climate change, and women being the front-runners by being disproportionately affected. Between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year from malnutrition, malaria, diarrhea, and heat stress alone. The direct damage costs to health are estimated to be between 2–4 billion US dollars per year by 2030 [1].

The relationship between female health and climate change is a complicated, multidimensional problem with broad ramifications. Women are more vulnerable to the effects of climate change than men – primarily as they constitute most of the world's poor and are more dependent for their livelihood on natural resources that are threatened by climate change. Women often have a strong body of knowledge and expertise that can be used in climate change mitigation, disaster reduction, and adaptation strategies. Furthermore, women's responsibilities in households and communities, as stewards of natural and household resources, position them well to contribute to livelihood strategies adapted to changing environmental realities [2]. Infertility is a major problem in modern society and recurs in as much as 17.5 % of the estimated lifetime prevalence of infertility in 2022 [3]. The American Society of Reproductive Medicine (ASRM) delineates infertility as failing to conceive after one or more years of attempts at natural fertilization, with the World Health Organization (WHO) reporting that up to 80 million women worldwide have been affected by this disease to date, with a prevalence of ~50 % of all women in developing countries [4].

India is a populous country with the population of 1.42 billion people and overall a developing country with the largest size of population in the world. In the recent years, India has crossed the border with China and became the most populous country with a healthy reproductive population. Even though India is a highest population country, the fertility rates in India have dropped from 5.622 to 2.12 in the past six decades. There are various reasons for the reduced fertility like poverty social initiatives but increased temperature and climate change have also contributed to reducing fertility rates recently [5]. The average annual temperatures in India are projected to be increasing between 1.7 and 2.2 °C by 2030, with an increase in the intensity and duration of heat waves all along the Indian subcontinent [6]. The number of deaths has already increased due to high temperature over the past 15 years, and as reported by various researchers [7–9]. Various studies have reported on heat-related health effects in women especially in aged and pregnant women [10–12]. Women have higher metabolic rates; the occurrence of thicker subcutaneous fat reduces their radiative cooling and dissipates less heat by sweating [13]. Other factors, like poor access to healthcare and reduced cooling facilities due to safety with culturally prescribed heavy garments, reduce evaporative cooling and, there is a lack of awareness among women about heat vulnerabilities.

2. Consequences of Climate Changes

Numerous approaches exist for environmental influences to impact female fertility health patterns where it can be affected by a variety of exposures, lifestyle decisions, and environmental factors with a wide range of direct and indirect consequences, which will be the subject of a broad discussion in this review.

2.1 Heat Stress

Heat waves are becoming more common and intense because of rising global temperatures. The scale and nature of the health impacts of heat depend on the timing, intensity and duration of a temperature event, the level of acclimatization, and the adaptability of the local population, infrastructure and institutions to the prevailing climate [1]. Mammals, including humans and livestock animals, are living in such a modifiable environmental condition. Most mammals have body temperatures of 35–39 °C [14]. These temperatures are maintained above environmental temperatures through the generation of metabolic heat. Body temperatures are normally maintained in a narrow range by heat production and loss, although disease, poor nutrition, and extreme environmental temperatures can upset the balance [15]. Inconsistent menstruation and polycystic ovarian syndrome (PCOS) are two other disorders that are known to be exacerbated by heat stress, thereby influencing female regular ovulation cycle. Young girls who are having irregular periods for a longer time are at greater risk of developing gynecological problems resulting in an increased risk of PCOS and other reproductive diseases [16]. Extended exposure to high temperatures can cause menstrual cycle disruption and hormone imbalance, which can have a detrimental impact on the reproductive health of women. Exposure to higher temperatures was found to be associated with a lower ovarian reserve. The results from an association study comprising 631 study subjects attending the Massachusetts General Hospital Fertility Center (2005–2015) who participated in the Environment and Reproductive Health Study, between ambient temperature and antral follicle count (AFC), a standard measure of ovarian reserve has raised a concern that rising ambient temperatures worldwide may result in accelerated reproductive aging among women [17, 18]. Heat stress can affect ovarian follicle growth in females, which is important for healthy ovulation and conception. Issues with fertility may arise from modifications in follicular development. A pre-clinical chronic heat-stress study comprising 48 female mice after exposure to a constant temperature of 25 °C for 7, 14, 21 or 28 d (n = 6) or to 42 °C for 3 h per d for 7, 14, 21 or 28 d (n = 6), has shown a decrease in serum estradiol and aromatase in antral follicles but increased number of atretic follicles and

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granulose cells undergoing apoptosis, which may explain the decreased fertility commonly observed in heat-stressed animals [19]. As reported, the secondary sex ratio at birth (male/female) may also be affected by changes in environmental temperatures [20, 21].

2.2 Food Security

Access to adequate, safe, and nutritious food is a prerequisite for food security, which is essential for overall well-being, including reproductive health. Climate change is likely to worsen the food security situation through its impact on food production, which may indirectly affect fertility behavior [22]. Reproductive health can be promoted by eating a diet that is well-balanced and rich in necessary nutrients but with a change in climatic trends and the effect it may have on food security and agricultural output is not to be overlooked. Climate change may have an impact on food production and availability, which could alter food prices and accessibility. Climate shocks create a strain on food production, transportation infrastructure, and access to food for much of the vulnerable population [23]. Changes in agricultural practices brought on by climate change affect the nutritional content of food, which may affect fertility and reproductive health. Malnutrition and food shortages can directly affect the reproductive health of women, influencing both mother and child health and fertility. Deficient food intake, inadequate alimentary regimes, strong dietary restrictions, and a general lack of nutrients result in loss of both body weight and physical performance, delayed puberty, lengthening of the postpartum interval to conception, lower gonadotropin secretion levels with alterations of the physiological ovarian cyclicity, and increased infertility. Poor intake of proteins, micro- and macro-minerals, and vitamins is associated with a reduction in reproductive performance since the altered energy balance correlates with the reduced ovulatory maturation in women [24]. Thus, inadequate nutrition is closely linked to female reproductive pathophysiology. This is confirmed by the fact that both bulimia nervosa and anorexia, namely two pathologic conditions affecting 5 % of women of childbearing age, are indisputable causes of amenorrhea, infertility, and miscarriages [25]. In females, reproduction involves much greater energy expenditures than for males and as a protective mechanism against under nutrition, ovarian activity is suppressed in women with eating disorders and exercise-induced amenorrhea through pathways in the hindbrain. The combined prevalence of Bulimia nervosa and Anorexia nervosa is approximately 5 % among women of reproductive age. Both disorders suppress ovulation in severely affected women and account for up to 60 % of women with an ovulatory infertility [26].

2.3 Water Scarcity

The interdependence of water, agriculture, economics, and health highlights the significance of tackling water scarcity as a component of larger initiatives to advance sustainable development and enhance quality of life. Water scarcity can have complex effects on reproduction that damage both human well-being and agricultural output (Table 1). Unsafe water can also interfere with people's reproductive health, for example, by increasing the chances of experiencing infertility or jeopardizing a person's

Table 1. **Effects of water scarcity**

Таблица 1. **Влияние дефицита водных ресурсов**

	Water scarcity / Дефицит водных ресурсов
Agricultural impact / Влияние на сельское хозяйство	Agriculture depends on water, and a lack of it can result in lower agricultural production and crop yields. Crop failure or reduced crop quality can arise from inadequate water for irrigation. / Сельское хозяйство зависит от воды, и ее нехватка может привести к снижению сельскохозяйственного производства и урожайности. Неурожай или снижение качества урожая может возникнуть из-за недостаточного количества воды для орошения.
Economic impact / Влияние на экономику	For numerous people globally, agriculture is a key source of income. Farmers who experience water scarcity may find their incomes are negatively impacted by decreasing agricultural yields. / Для многих людей по всему миру сельское хозяйство является основным источником дохода. Фермеры, испытывающие нехватку воды, могут обнаружить, что снижение урожайности сельскохозяйственных культур негативно сказывается на их доходах.
Population displacement / Перемещение населения	People relocate in the quest for better living conditions and access to water resources, which can lead to population displacement because of water scarcity. Changes in population density and demographics may result from this shift. / Люди переселяются в поисках лучших условий жизни и доступа к водным ресурсам, что может привести к перемещению населения, вызванному дефицитом воды, и, как следствие, к изменениям плотности и других демографических характеристик населения.
Health impact / Влияние на здоровье	There may be negative health effects in areas with water scarcity, such as the spread of diseases that are transmitted through the water because of poor sanitation and hygiene. / В районах с дефицитом воды возможно распространение инфекционных болезней, передающихся через воду, из-за нарушений санитарно-гигиенических норм водоснабжения.
Climate change connection / Связь с изменением климата	Changes in precipitation patterns and increased evaporation brought on by climate change might make problems with water scarcity worse. Water supply and agricultural systems may be further impacted by these changes. / Изменения частоты и количества осадков, а также повышенное испарение, вызванные изменением климата, могут усугубить проблемы с нехваткой воды. Водоснабжение и сельскохозяйственные системы могут еще больше пострадать от этих изменений.

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ability to have a healthy pregnancy [27]. Droughts have direct physiological effects on organisms, such as an increased risk of lethal dehydration that can cause mass mortality events and rapid population declines in birds, mammals, and amphibians with potential impacts on trophic networks and communities [28]. Reproductive tract infections and pregnancy difficulties can be made more likely by not having access to clean water and sanitary facilities.

2.4 Psychosocial Stress

Climate change brings exposures to heat, air pollution, poor quality food, and infectious diseases that have significant direct effects on women and their mental health. These environmental impacts are multifaceted in their consequences and raise risks of depression, suicide, violent victimization, post-traumatic stress disorder, and various other neuropsychiatric symptoms [29]. Extreme weather,

Table 2. **Physiological stress caused by climate change**

Таблица 2. **Физиологический стресс, вызванный изменением климата**

Climate change / Изменение климата	Psychosocial stress / Психосоциальный стресс
Displacement and migration / Переселение и миграция	Droughts, rising sea levels, and other climate-related extreme weather events can lead to migration and displacement. Due to their potential vulnerabilities–such as having limited access to resources or being responsible for providing care for others–women are frequently disproportionately affected. Psychosocial stress can arise from displacement due to the loss of social networks, heightened economic challenges, and feelings of insecurity. / Засухи, повышение уровня моря и другие экстремальные погодные явления, связанные с климатом, могут привести к миграции и перемещению населения. Из-за своих потенциальных уязвимостей, например, ограниченного доступа к ресурсам или ответственности за обеспечение ухода за другими людьми, женщины часто страдают в непропорционально большей степени. Перемещение может вызвать психосоциальный стресс вследствие потери социальных связей, обострения экономических проблем и чувства незащищенности.
Resource scarcity / Дефицит ресурсов	Scarcity can result from changes in climatic patterns that affect resources like food and water. In many communities, women are the primary caretakers and are in charge of obtaining these resources. Stress, anxiety, and conflict within communities can be caused by increased competition for scarce resources. / Дефицит может быть результатом изменений климатических условий, которые влияют на такие ресурсы, как еда и вода. Во многих сообществах именно женщины являются хозяйками, ответственными за получение этих ресурсов. Стресс, беспокойство и конфликты внутри сообществ могут быть вызваны возросшей конкуренцией за скудные ресурсы.
Health impacts / Влияние на здоровье	Disease patterns are changing, vector-borne infections are becoming more common, and infectious diseases are spreading due to climate change. Because of their care giving responsibilities and restricted access to healthcare, women, especially in underdeveloped nations, may be more vulnerable to health concerns, which can lead to psychological stress. / Меняется структура заболеваемости, трансмиссивные болезни становятся все более частыми, а инфекционные заболевания распространяются из-за изменения климата. Из-за своих обязанностей по уходу за другими членами семьи и ограниченного доступа к услугам здравоохранения женщины, особенно в слаборазвитых странах, могут быть более обеспокоены проблемами со здоровьем, что может привести к психологическому стрессу.
Gender Based Violence / Гендерное насилие	Stressors associated with the climate might intensify pre-existing vulnerabilities, such as gender-based violence. There may be a greater risk of violence against women due to displacement, resource constraint, and shifting social dynamics, which could cause psychological anguish. / Факторы стресса, связанные с климатом, могут усилить уже существующие уязвимости, такие как гендерное насилие. Вероятен более высокий риск насилия в отношении женщин вследствие переселения, ограниченности ресурсов и изменения социальной динамики, способный вызвать психологические страдания.
Role strain / Ролевое напряжение	Women often play crucial roles in their families and communities, and climate change can disrupt these roles. For example, increased responsibilities due to the impacts of climate change, such as caring for family members affected by disasters, can lead to role strain and psychological distress. / Женщины часто играют важные роли в своих семьях и сообществах, а изменение климата может их подорвать. Возросшая из-за последствий изменения климата ответственность, например забота о членах семьи, пострадавших от стихийных бедствий, может привести к ролевому напряжению и психологическому стрессу.
Cultural and social disruption / Культурные и социальные потрясения	Climate change has the potential to upend established lifestyles, including social institutions and cultural customs. These interruptions can cause social isolation, identity conflicts, and a sense of loss, which can put females under psychosocial stress. / Изменение климата может кардинально воздействовать на привычный образ жизни, включая социальные институты и культурные обычаи, приводя к потенциальной социальной изоляции, конфликтам идентичности и чувству утраты, которые способны вызвать психосоциальный стресс у женщин.

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temperature increases, sea level rise, and environmental degradation are just a few of the repercussions of climate change that can have a significant negative impact on people's mental health and general well-being. It is becoming more widely acknowledged that psychosocial stress is significantly influenced by climate change, which has an impact on both individuals and societies on multiple levels. Periodic stress has been connected to irregular menstruation and problems with fertility. Stressful stimuli cause the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic-adrenal-medullary (SAM) axis [30]. The hormones secreted by these systems after stressful stimuli result in an abnormal, prolonged and/or excessive stress-induced body's set-up that can potentially produce long-term neuroendocrine changes, affecting female fertility [31]. All stress-induced hormones from the adrenal cortex and medulla are responsible for several physiological and mental consequences, which cause the individual to fight with or flight from the stressor. Differences in individual responses could be explained by findings from ewes showing that animals with divergent cortisol responses to ACTH exhibit functional differences in the HPA axis due to innate differences in the gene expression/function of HPA molecules [32]. Further results from female Cynomolgus monkeys, exposed to mild combined psychosocial and metabolic stress, show a selected and specific (rather than generalized) increased activity in the adrenal framework significantly related to stress-induced reproductive dysfunction [33].

2.5 Emerging Pollutants

Environmental pollution, which exerts potentially harmful effects on earth and atmospheric ecosystems, is caused by the presence of chemical, biological, and physical substances deemed pollutants [34, 35]. Pollutants can originate from a variety of sources, such as the air, water, food, and workplace environments. Pollutant persistence and distribution can be impacted by climate change. Hormone regulation may be disrupted by exposure to certain pollutants, such as endocrine-disrupting chemicals, which can affect reproductive health. The most common direct or indirect causes of female infertility are advanced age, endocrine problems and damage to the reproductive apparatus (vaginal, cervical, uterine, tubal, and pelvic-peritoneal diseases). Premature ovarian insufficiency (POI), endometriosis and polycystic ovarian syndrome (PCOS) or sexually transmitted diseases have widely recognized roles in fertility failure, although approximately 15–30 % of cases remain unexplained [36, 37].

3. Conclusion

The climate of the Earth has naturally fluctuated over geological time spans. However, over the past few decades, human activity has significantly changed the climate, leading to both climate change and global warming. This has led to rising sea levels, altered ecosystems, and an increase in the frequency and intensity of extreme weather events. Part of the effort to tackle climate change includes the implementation of international agreements such as the Paris Agreement, which aims to reduce greenhouse gas emissions and limit rises in global temperature. While adaptation techniques work to assist populations in adjusting to the effects of climate change, mitigation measures concentrate on lowering emissions. Global efforts to combat climate change must also prioritize the development of renewable energy technologies, sustainable behaviors, and public awareness. A comprehensive and inclusive strategy that takes into account the particular vulnerabilities and roles that women play in many civilizations is needed to address the nexus of female health and climate change. Faced with climate change, advocacy, education, and legislative actions can help to increase women's resilience and reduced the negative effects on their health. It is critical to recognize that these relationships are complex and that a range of variables, including geography, socioeconomic status, and underlying medical issues, may have an impact. Furthermore, research on the effects of climate change on the health of female reproductive systems is still underway, and as scientists look further into these intricate relationships, new knowledge may become available. Mitigation techniques and climate change adaptation may be essential for maintaining environmental sustainability and human health, especially reproductive health. A comprehensive strategy that incorporates gender-sensitive legislation, community resilience-building, and climate change mitigation techniques is needed to address the psychosocial effects of climate change on women. Understanding the intersectionality of vulnerabilities and addressing the particular difficulties experienced by women in various situations are crucial. It is important to remember that different factors, including exposure type and level, individual sensitivity, and exposure duration, might have different effects on female fertility for chemical contaminants. Furthermore, this field is still being researched, and fresh discoveries could shed more light on the connection between particular contaminants and female fertility. People can take steps including limiting exposure to known dangerous chemicals, maintaining a healthy lifestyle, and staying knowledgeable about environmental factors that may affect reproductive health to avoid the dangers linked with chemical pollution and female fertility. Seeking counsel and help from healthcare professionals or reproductive specialists can be beneficial if issues emerge. A comprehensive strategy that takes into account sustainable farming methods, healthcare access, economic empowerment, and nutritional education is needed to address the complex interactions between female reproduction and food security. Communities' general growth and well-being can benefit from policies and initiatives that work to enhance both food security and reproductive health. One should keep in mind that this field is complex and constantly changing, and our understanding of these relationships is always expanding.

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Table 3. **Stress related to chemical pollutants**
Таблица 3. **Стресс, вызываемый химическими загрязнителями**

Chemical pollutant / Химический загрязнитель	Stress / Стресс
Endocrine disruptors / Эндокринные разрушители	The endocrine system, which controls the body's hormonal balance, can be interfered with by some substances, referred to as endocrine disruptors. Exposure to pesticides has shown to have decreased ART clinical pregnancy and live birth rates [38, 39]; bisphenol A & DEHP found in contaminated food, consumer products and packaging/cleaning and building materials decrease oocyte yield, decreased normal fertilization and increased risk of miscarriage [40–46]. / Эндокринная система, регулирующая гормональный баланс организма, может пострадать от веществ, называемых эндокринными разрушителями. Было показано, что воздействие пестицидов снижает эффективность вспомогательных репродуктивных технологий, показатели клинической беременности и живорождения [38, 39]; бисфенол А и диэтилгексилфталат, обнаруженные в загрязненных продуктах питания, потребительских товарах, чистящих средствах, упаковочных и строительных материалах, снижают выход ооцитов, препятствуют нормальному оплодотворению и повышают риск самопроизвольного выкидыша [40–46].
Persistent organic pollutants / Стойкие органические загрязнители	POPs include substances such as dioxins, polychlorinated biphenyls, and some insecticides which can build up in the body over time have been linked to decreased fertility, changed hormone levels, and irregular menstruation. Industrial chemicals such as persistent organic pollutants (POPs) have been associated with reduced fertility in women, including longer time-to-pregnancy, higher odds for infertility, and earlier reproductive senescence [47]. Female exposures to POPs are also associated with a gender imbalance in their offspring, when the natal sex ratio (male/female) may drop to 0.55 [48]. / Показана связь между воздействием стойких органических загрязнителей (СОЗ), напр. диоксинов, полихлорированных бифенилов и некоторых инсектицидов, способных накапливаться в организме с течением времени, и снижением фертильности, изменением уровней гормонов и нерегулярными менструациями. Промышленные химические вещества, такие как СОЗ, связаны со снижением фертильности у женщин, включая более длительное время до наступления беременности, более высокие шансы на бесплодие и раннее репродуктивное старение [47]. Воздействие СОЗ на женщин также связано с гендерным дисбалансом у их потомства, когда натальное соотношение полов (мужской/женский) может снизиться до 0,55 [48].
Air pollutants / Загрязнители воздуха	Particulate matter could affect fertility. Particularly short-term exposure during the onset of the secretory phase and at the time of the embryo implantation could have a detrimental effect on the endometrium reducing clinical pregnancy rate and increasing miscarriage rates [49]. Nitrogen dioxide and ozone were associated with a reduced live birth rate while particulate matter of 10 μm was associated with increased miscarriage [50]. The effects of long-term exposure to air pollution on fertility have been showed by some works [49, 51–55] and perinatal outcomes are also well documented [49, 56–62]. / Твердые частицы могут влиять на фертильность. В частности, кратковременное воздействие в начале секреторной фазы и во время имплантации эмбриона может оказывать пагубное влияние на эндометрий, снижая частоту наступления клинической беременности и повышая частоту самопроизвольного выкидыша [49]. Показана связь между воздействием озона и диоксида азота и снижением частоты живорождения, а также твердых частиц размером 10 мкм и увеличением частоты выкидышей [50]. В ряде работ было показано влияние длительного воздействия загрязнения воздуха на фертильность [49, 51–55] и перинатальные исходы [49, 56–62].
Heavy metals / Тяжелые металлы	The fertility of females can be adversely affected by heavy metals such as lead, mercury, and cadmium. These metals can build up in the body, causing problems with ovarian function, hormone balance, and an increased chance of miscarriage. Environmental and occupational exposure to metals impairs female reproductive health by affecting the reproductive system at all strata of regulation and functions, resulting in female infertility, menstrual disorders, spontaneous abortion, endometriosis, endometrial cancer, breast cancer, etc. [63] Basic and clinical studies have been reported on the adverse effects of Cd, Pb, Hg, and As exposure to female infertility [64]. The female nickel exposure is associated with birth defects in their offspring, small-for-gestational age, perinatal mortality and spontaneous abortions [65–67]. / На фертильность женщин могут негативно влиять тяжелые металлы, такие как свинец, ртуть и кадмий. Они способны накапливаться в организме, вызывая дисфункцию яичников и гормональный дисбаланс, а также повышая вероятность выкидыша. Воздействие металлов в окружающей среде и на производстве ухудшает репродуктивное здоровье женщин, влияя на репродуктивную систему на всех уровнях регуляции и функций, что приводит к женскому бесплодию, нарушениям менструального цикла, самопроизвольным абортам, эндометриозу, раку эндометрия, раку молочной железы и т. д. [63]. Опубликованы данные базовых и клинических исследований Cd, Pb, Hg и As как факторов риска женского бесплодия [64]. Воздействие никеля на женщин связывают с врожденными пороками развития у их потомства, задержкой роста плода, перинатальной смертностью и самопроизвольными абортами [65–67].

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