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Effects of Exposure to Environmental Pollutants on Male Fertility

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ABSTRACT

Idiopathic infertility is when an individual can't conceive or have children, but the physicians are unable to identify a definitive cause. This is the most frequent form of male infertility, making up approximately 44% of cases. Over the past 50 years, research has indicated that the fertility of men has been declining, but not due to being overweight, identified genetic issues, or dietary or lifestyle changes. Parallel to this, humans are increasingly being exposed to more man-made chemicals. Some of these chemicals are not toxic, but others may influence the body's hormones and cause harm to sperm. The U.S. National Toxicology Program keeps on hand a list of more than 80,000 chemicals and around 2,000 new chemicals are added yearly. They are phthalates, polycyclic aromatic hydrocarbons, aromatic amines, and organophosphate esters, which are toxic and either restricted or prohibited in other nations due to their cancer-causing and reproduction-damaging effects. Most of these chemicals are still utilized in the U.S., and exposure levels individuals receive can be harmful to reproduction. This compares with other areas such as the European Union, where there are stricter regulations under systems like REACH, which touches more sectors and has more stringent guidelines. It is difficult to properly measure how much exposure each of them has to these chemicals, but developing technology can assist here. Although it's not yet possible to predict exactly how much idiopathic infertility is due to exposure to environmental toxins, there's value in ongoing investigation, limiting exposures to toxic chemicals, and minimizing risks for improving reproductive health. This review considers evidence

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indicating associations between alterations in male fertility and total environmental exposure. These include pesticides and herbicides such as DDT, DBCP, organophosphates, and atrazine, endocrine disrupter's phthalates and BPA, heavy metals, oil and natural gas, non-ionizing radiation, air pollution and noise pollution, lifestyle exposures such as diet, obesity, caffeine, smoking, alcohol, drug use, and typical medications.

Introduction

Others would talk endlessly about the perception that men have it harder than ever before to make women pregnant, but nowadays it is no longer so widely talked about.(Tannen et al,.1990) Most of the evidence shows that among Western men, both the amount of semen they ejaculate as well as the quality of their semen has reduced in the recent past. This may not necessarily be caused by factors like obesity, drug use, excessive smoking, and alcoholism. (Bush et al, .2014) It may also partly be caused by long-term exposure to harmful chemicals in the environment. This, however, is not well researched on how the chemicals do affect sperms. Most of the toxins are extremely dangerous if exposed to them at once, but most of those harmful to the sperm are present in tiny amounts over an extended period. The poisons even reduce sperm count when consumed in much higher amounts than humans subject themselves to, as per animal studies. (Mima et al, .2018) Moreover, most of the research utilizes outdated information and controls for variables aside from the poison that can influence outcomes. The research fails to control for geographic or ethnic diversity, which has the potential to affect sperm production in varying ways. Even the male population unable to conceive is not representative of the overall population. In spite of the difficulties, this review takes into account the current literature on how prevalent environmental toxins impact sperm development. (Kumar et al, .2022)

The Impact of Environmental Exposures

The teaser points to increasing alarm regarding environmental exposures that may reduce the fertility of men. The majority of poisonous chemicals found in everyday life are readily available, and long-term effects on fertility are a serious concern. (Krzastek et al, .2020)Although little has been researched about the long-term effects of exposure to environmental poisons, including those of nuclear accidents or

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Superfund sites, there are indications that some toxins initiate birth defects and preterm labour. This would mean that widespread environmental contamination, such as at Superfund sites, can have a harmful effect on fertility. Environmental Protection Agency (EPA) also identifies that exposure to dangerous chemicals in this regard is able to pose threats to fertility. Thus, environmental exposure should be taken into account while determining the potential for fertility. (Persico et al, .2020)

Mechanistic comprehension of the effects of environmental pollutants on sperm quality Organisms are affected by injurious agents that come from non-living aetiologies. The level of effect ranges with exposure duration and severity, as well as the organism's genetically controlled protective systems. Genetic variations influence the xenobiotic metabolism in individuals, thus varying in their reactions to environmental contaminants. (Van et al, .1992) Human susceptibility also differs with age, weight, sex, race, pre-existing state of health, and pre-existing medication on board. Additionally, male fertility potential is affected even prior to conception. (Petrelli et al, .2002) Parent gametes' physical and environmental health may impact the reproductive potential of male offspring. This is evidenced by findings gained from fetal development research, for example, phthalate syndrome. Males' fertility may be compromised by a number of exposures to various environments across all stages of life. Organochlorine pesticides and dioxins are among the examples of persistent pollutants that are resistant to metabolic degradation and have a potential for biomagnifying and bioaccumulation in fatty tissues, liver, kidneys, and bones. (Vassilopoulou et al, .2017)

Air Pollution

Air pollution is increasing in all the world's major cities today, which is severely hampering human health. It has been responsible for various risks of diseases like cancer, respiratory diseases, cardiovascular diseases, skin disease, and reproductive diseases. (Shetty et al, .2023) The main causes of the pollution are vehicles, industries, burning, houses, agricultural farms, dumpsites, oil refineries, and natural events like wind and volcanic eruptions. The most significant groups of health-damaging pollutants include particles, volatile organic compounds, ozone, nitrogen oxides, sulphur dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, and

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radiation in the form of X- rays. Air pollution impacts both men's and women's reproductive health significantly. Men's fertility is affected by reducing sperm quality. Evidence indicates air pollution to cause damage to sperm DNA, alter sperm shape, and decrease mobility. (Kleshchev et al, .2021) Studies have also established that high pollution has high positive correlations with decreased semen volume, decreased sperm count, decreased motility of sperm, and decreased normal morphology of sperm. It also increases the fragmentation of sperm DNA further decreasing fertility. (González-Marín et al, .2012) Another study has recently examined the correlation between some gases and semen quality. It found that exposure to sulphur dioxide influences different parameters of sperm at different exposure levels. It further observed that sperm motility and density, which are more pronounced in early stages of sperm development, are adversely influenced by sulphur dioxide as well as nitrogen dioxide. Thus, it is evident that gaseous pollutants have a very significant contribution to lowering the quality of semen, particularly when the sperm is in the process of maturation. (Deng et al, .2016) Exposure to auto emissions, particularly the type containing lead and nitrogen oxides, is highly linked to an increase in declining semen quality. Individuals exposed to high concentrations of traffic-derived pollutants have elevated sperm DNA fragmentation rates and chromatin structural problems relative to non-exposed individuals. All these results validate the hypothesis that prolonged exposure to car exhaust can lead to genetic stress on human sperm, representing a severe risk to male reproductive health. (Kumar et al, .2022)

Dioxins and Furans

When burning of organic wastes, particularly those with chlorine or sewage sludge, takes place during municipal waste incineration, certain toxic chemicals are emitted into the environment. Some of these chemicals, particularly dioxins, are highly toxic and can be stored in fat tissue for 7 to 11 years. (EFSA et al, .2018)Dioxins have been associated with a wide range of health problems such as cancer, congenital abnormalities, and reproductive disease. The toxins are reported to interact with aryl hydrocarbon receptor (AHR) and aryl hydrocarbon receptor nuclear translocator (ARNT) partner proteins that occur in human testicular cells, leading to negative impacts on male fertility. The comparison analysis of 135 dioxin-exposed

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men at three stages of their life cycle—pre-puberty, puberty, and post-puberty—and 184 unexposed men reported pre-puberty exposure as linked to low motility and sperm concentration.(Dhooge et al,.2006) Children of mothers who were exposed in childhood with high dioxin levels had reduced sperm count, concentration, and motility later in life. Even when the data was compared, the men with infertility had 2.2 to 2.3 times greater concentrations of dioxins and furans in their semen than men who could conceive. The research highlights the major role played by dioxins in the male's reproductive function as well as sperm quality. (Aldeli et al, .2024)

Endocrine-Disruptor Chemicals

Most all household chemicals can hurt the endocrine system of backbone animals. The system allows the body to remain in balance and manage such important things as growing, remaining healthy, and birthing. (Thompson et al, .2001) More and more poisonous chemicals have found their way into the environment during the last decades, such as pesticides, fire retardants, some oils, electrical device chemicals, plasticizers, and some metals. These chemicals mimic hormones or interfere with hormones functioning properly, and they are known as endocrine-disrupting chemicals, or EDCs. EDCs are naturally occurring and synthetic chemicals that find their way into the environment via air, soil, water, and food. Water is of special concern since the chemicals tend to bioaccumulation in the food web, and consequently, human beings are in contact with them, particularly via the consumption of fish and shellfish. (Darbre et al, .2022) The general public is exposed to the chemicals via what they consume, which is the primary route of entry of EDCs and other harmful chemicals into the body. Researchers have seen glaring issues with fish and other aquatic animals breeding, and one of them is the spectacular decline in fish population in fresh water regions. (Arthington et al., 2016)

Effect of Endocrine Disruptors on Sperm Quality

Endocrine disruptors (EDCs) have been stated to be capable of interfering with normal functions that hormone-controlled processes, like sexual development and reproduction, achieve. Endocrine disruptors are termed so due to their capability of mimicking or blocking steroid hormone action. Individuals as well as scientists have raised serious doubts regarding the adverse impact of these poisons, like organ chlorinated pesticides (OCPs) and polychlorinated biphenyls (PCBs), which are the

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causatives of a series of diseases from birth defects to brain, liver, kidney, immune system, and even cancer.(Jayaraj et al,.2016) "Endocrine disruption" has been first described as early as 1991, and the initial studies were more keen on the manner in which these chemicals mimic estrogens and hence are referred to as xenoestrogens. Experiments with living organisms and laboratory tests have shown that a wide range of chemicals exhibit estrogens, anti-estrogens, testosterone, or anti-testosterone activity. The disruption of reproduction through endocrine is colloquially known as they disrupt hormone function and thus, do not let them carry out their usual function. (Lister et al, .2001) For instance, the hypothalamus secretes a hormone known as gonadotropin-releasing hormone (GnRH), which releases the pituitary gland to secrete follicle-stimulating hormone (FSH) and luteinizing hormone (LH). Upset in any of the processes can jeopardize sperm quality and production. Production and sperm quality are regulated in some stages. (Cabrita et al, .2008)

Pollution by Plastics and Plasticizers

Scientists utilize machine learning and some process in order to acquire information about the plastic flow in the environment. The exercise results in approximately 52 million tons of plastics entering the environment. (Rhodes et al, .2019)Even though the plastics are toxic, more so in relation to reproduction, human beings continue using them widely daily. Some chemicals such as BPA typically leave the body within six hours, primarily through urine. It is present in nearly every individual. In the United States of America, about 92.6% of individuals over the age of six possess BPA in their body.(Zhang et al,.2024) Some chemicals too stay for an extended period of time in the body. These types of plastics can evaporate and diffuse by air. Human beings are continuously inhaling these chemicals, particularly those airborne as pollutants. These toxic chemicals migrate by sea and air for hundreds of kilometres, and already possess the existence of such chemicals in animals, such as polar bears. Such animals are at the top of the food chain and possess such chemicals in their body. Scientists believe that this indicates that toxic chemicals migrate long distances by sea and air. Exposure also takes place in homes and workplaces where individuals reside and work. This harms the exposed individuals through their workplace, an essential fact of what makes chemicals harmful to the body. (Rodricks

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et al., 2006)

Microplastics, Nanoplastics and Sperm Quality

Microplastics are little pieces of plastic that range from 1 micrometer to 5 millimetres. Microplastics also turn into tiny fragments that are usually below 1 micrometer. (Snow et al, .1984). Macroplastic fragments remain in the environment for many years before they break down under natural conditions. Microplastics are found in many places, such as the atmosphere, water, soil, and even food. They are toxic even when incredibly small. The most frequently encountered microplastics include polyethylene, polypropylene, and polyvinyl chloride. (Lieshchova et al, .2019).Research has found tiny fragments of plastic within the faeces of humans. There is growing concern because microplastics have been found in the bodily fluids of humans, including urine. Microplastics such as polyvinyl acetate, polyvinyl chloride, and polyethylene are found by scientists with advanced imaging methods. Because the plastic particles are becoming more common, people are becoming increasingly interested in possible health effects, especially on male fertility and the reproductive tract. Studies have created a strong connection between exposure to plastic particles and lowered concentrations of hormones like follicle-stimulating hormone, luteinizing hormone, and testosterone. (Tyc et al, .2025)

Conclusion

We are constantly exposed to environmental toxins, and this can perhaps be one reason for reduced fertility in men. There is evidence pointing towards the fact that these exposures are carrying over into reduced fertility, but proving that they have been found as direct causes has not yet been done. That's because the impacts of long-term exposures take a very, very long time and are extremely widespread to investigate. It is also hard to test other environmental factors because. There are very strict ethical guidelines. Although these poisons have an impact on fertility, we cannot know whether they actually contribute to fewer successful pregnancies. So we cannot know for sure that they are the key cause of falling fertility. That is why we should try to cut off our exposures to poisonous environmental chemicals as much as it is possible. The well-being of our descendants relies on governmental actions to limit such exposures, such as prohibiting some hazardous chemicals and establishing maximum safe levels for others. We should do something today to

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prevent serious problems before they are problems. That is what is being done nowadays. New and novel approaches are helping to place the risks posed by environmental exposure into clearer perspective and necessitating thoughtful, thoughtful changes.

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