Review Article

Journal of Occupational Health and Epidemiology
Journal homepage: http://johe.rums.ac.ir

Association between Occupational Chemical Exposure and Sperm Parameters; A Narrative Review

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Citation: Pourmasumi S, Vazirinejad R, Ahmadi Z, Mehdipour A, Nazari A. Association between Occupational Chemical Exposure and Sperm Parameters; A Narrative Review. J Occup Health Epidemiol. 2023;12(1):50-8.

Article Info

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Article history
Received: Sep 2022
Accepted: Dec 2022

10. 61186/johe.12.1.50

Print ISSN: 2251-8096
Online ISSN: 2252-0902

Peer review under responsibility of Journal of Occupational Health and Epidemiology

Abstract

Background: Infertility is a major problem around the world. The male partner is responsible for half of the infertility. Several factors can affect the male reproductive system and create infertility. Occupational exposure is one of the main factors in male infertility. Present study aimed to review the literature on chemical occupational exposure effects on male fertility.

Materials and Methods: For this narrative review online search was conducted on scientific databases including PubMed, Scopus, and Web of Sciences by the following keywords: male fertility/infertility, sperm, occupational, chemical agents, work environment, pesticides painters, farmers, and farmworkers. In this study, we categorized sperm characteristics (quality, count, mobility, morphology, and viability) and reviewed studies (between 1985 – 2022) that assessed chemical occupational effects separately (chemical industries, farmers, and painters) on sperm characteristics. We tried to review the most recently reported studies in this issue and categorized them into subgroups for easy understanding.

Result: Most studies reported a positive association between chemical exposure and defects in sperm parameters. Existing research suggests that the association between industrial life and infertility development is probably reciprocal.

Conclusion: Results of the studies are controversial, and it seems epidemiological investigations cannot approve the harmful effects of some occupational chemical exposure on fertility potential and sperm parameters. During interpreting the results of the studies, it is important to emphasize that the type of chemical mixtures, duration of exposure (chronic exposure to different levels), and number of compounds, physiological and psychological conditions can play a key role.

Keywords: Occupation, Chemical Industry, Sperm, Infertility

Introduction

Infertility definition is a condition that couples cannot achieve a child after at least one year of non-protected intercourse. Infertility is dependent on several factors and can occur in both female and male partners. On average, around 15% of couples worldwide struggle with infertility [1].

In women, infertility is associated with ovulation disorders, uterus, fallopian tubes, and hormonal disorders. Women with hormonal disorders, irregular periods, and hairiness are at higher risk [2,3].

Opposing to general acceptance, not only women are the cause of infertility, but males also are responsible for half of the infertility [4]. Despite the importance of male infertility, infertility evaluations have traditionally focused on women because men often believe they are not infertile and do not need infertility counseling [5]. Several parameters can affect male fertility; some of those including anatomical defects (cryptorchidism, testicular hernia, varicocele…), lifestyle (smoking, occupational condition, obesity), hormonal disorders, and disease (thyroid, cancer, diabetes…) [6-8].

The impact of the work environment on male fertility varies from person to person, and many people who work in high-risk jobs may never experience infertility [9]. Industrial life, especially in developing countries, is a main factor for male infertility. Some industrial and chemical jobs might cause infertility in men [10]. The results of studies in the last 50 years show that the quality and quantity of sperm in men have decreased, and this has caused the investigation of environmental factors affecting human health [11,12].

The focus on the effects of occupational parameters, including pesticides, exogenous estrogens, toxins, and heavy metals, on the male reproductive system, is not new and started about 50 years ago (1970) [13]. Five years later, in 1975, Lancranjan et al. reported that workers exposed to lead showed defects in fertility [14]. Several studies published and suggested environmental factors can create infertility in both males and females [15, 16]. In Iran, scientific reports confirmed the negative effects of occupational and environmental exposures on the risk of infertility [17, 18].

The process of spermatogenesis in humans takes about 3 months (72 days). In this period, any toxicological factor can disrupt spermatogonia cell division and spermatocyte differentiation in testis seminiferous tubules. Consequently, sperm characteristics (concentration, motility, and morphology) might be affected, and chromatin quality could be decreased [19]. One of the initial and main ways to identify fertility in men is seminal analysis. Analysis of fresh seminal fluid immediately after ejaculation refers to one or more sperm characteristics, including count (millions/ml), motility (% motile and immotile), morphology (% normal), and viability (%) that can show fertility potential [20,21].

Usually, based on scientific epidemiological studies, occupational effects have been divided into several parts, such as physical (heat, welding, and radiation), chemical (metals vapor and pesticides), and psychological (distress, fear, and anxiety) [22, 23].

Numerous studies have investigated the effect of occupational factors on male fertility and reported environmental and occupational effects on total sperm analysis. The results of the studies are contradictory. Some studies have confirmed that chemical, and environmental parameters negatively affect male fertility. Still, others did not report any disturbance in sperm parameters after exposure to chemical factors. Therefore, based on our knowledge, there is a gap in knowledge between the results of the studies. So, this study aimed to investigate and classify sperm parameters (quality, number, motility, morphology, and viability) based on occupational exposure to chemicals. We reviewed studies that assessed occupational chemical effects separately (chemical industries, farmers, and painters) on sperm characteristics. The results of our study can help in terms of the availability of the effects of each of the chemical occupational factors on sperm parameters.

Materials and Methods

For this narrative review, we searched online scientific databases, including PubMed, Scopus, and Web of Sciences, by the following keywords: male fertility/infertility, sperm, occupational, chemical agents, work environment, pesticide painters, farmers, and farmworkers. To conduct this narrative, we review all related English articles on the association between chemical exposure and sperm parameters between 1980 to 2022. 1763 full-text articles were found, of which 555 were free full-text.

The study excluded abstracts without full texts, letters to the editor, short communication, and case reports. Also, papers focusing on other fertility parameters (without sperm parameters), including sex hormone profile, sexual dysfunction, and testis morphometry, were excluded. Numerous studies have been published and focused on male fertility and chemical exposure, but we only selected studies that reported sperm parameters. We also reviewed systematic reviews and meta-analyses. We finally assessed 275 scientific papers; three independent researchers assessed papers and overlapped deleted articles. Identified articles were divided into three parts and reviewed by researchers. Based on the aim of the study,

data were extracted, and a manuscript was obtained.

Results

Chemical exposures: United States National Toxicology Program verified nearly 80,000 chemicals in the toxicant registry system and added about 2000 new annually. Numerous of these chemicals are known as toxic globally, including some pesticide components and their use is limited in several countries [24].

These chemicals' harmful effects are approved for some diseases, such as cancers and respiratory distresses [25, 26]. To date, several studies planned to verify the effects of occupational chemical exposure on male fertility [27-29]. Results of the studies are controversial and epidemiological assessments cannot approve the harmful effects of occupational chemical exposure on fertility potential and sperm parameters.

Finally, we reviewed recent studieson this issue and categorized them in subgroups for easy understanding. (Table 1).

Table 1. Brief main studies in the association between chemical exposure and sperm defects

Author	Study year	Conclusion
		Chemical production factories
Jelnes et al.	1988	Sperm motility, sperm normal morphology, and sperm viability significantly decreased in workers exposed to acetone in a plastic factory.
Naha et al.	2005	Sperm parameters defective in lead acid battery factory workers.
Cherry et al.	2008	Sperm concentration and motility decreased in workers who worked in glycol ethers used in manufactories
Goldstone et al.	2015	Seminal quality in workers who worked in chemical production factories was significantly decreased.
Gabrielsen et al.	2016	Low sperm concentration and high abnormal sperm morphologically in workers in the pesticide production factory.
Guo et al.	2016	Working with Carbon Disulfide can create several defects in sperm parameters.
Fucic et al.	2018	There were negative effects of chemical exposure on the sperm parameters of workers in plastic production factories.
Ianos et al.	2018	In patients with impaired seminal quality after the urinary test, some ethoxy-acetic acid (EAA) metabolites were detectable.
Danafar et al.	2021	Titanium dioxide exposure was a main parameter to decrease sperm parameters, especially sperm count and viability.
SHAH et al.	2021	In workers who worked in melting and furnace parts, sperm parameters were significantly lower than workers in textile chemical factories.
		Farmers
Henderson et al.	1986	Exposure to pesticides and occupational toxins is responsible for sperm defects in farmers.
Swan et al.	2003	Plant pesticides reduce sperm production, sperm count, sperm motility, and sperm normal morphology.
Sadighi et al.	2003	Abnormal sperm parameters (count and motility) were higher in farmers than in other jobs.
Hanke et al.	2004	In papaya farmers who use Ethylene dibromide (EDB), sperm parameters (count motility and normal morphology) significantly decreased.
Hossain et al.	2010	The rate of abnormal semen quality increased in agricultural workers after pesticide exposure.
Ben Abdallah et al.	2012	Dimethoate, as an organophosphorus pesticide, may cause a decrease in sperm parameters, especially sperm motility, and viability.
Mehrpour et al.	2014	Organophosphorus can decrease sperm count, motility, and viability.
Fucic et al.	2021	Sperm parameters spatially sperm motility decreased in greenhouses workers.
Knapke et al.	2022	Pesticide exposure was the cause of low semen quality in farm workers.
		Painters
Lemasters et al.	1999	There was low sperm motility in painter workers.
Kenkel et al.	2001	Sperm concentration and count significantly decreased in painters.
Hosni et al.	2013	Sperm parameters in painters have a significant decrease, especially sperm count and motility.
Irnandi et al.	2021	Defects in sperm quality of automobile painters were higher than the control group.

Chemical Production Factories: Seminal quality defects in some environmental and workplace settings! were confirmed in several studies from many years ago [30, 31].

Industrial solvents are also called industrial chemicals. The most important industrial solvents are the ethylene glycol group, and the most important are methoxyethanol and ethoxyethanol, also called organic solvents. These solvents are widely used in dyeing, painting, and thinner industries [32]. The results of the studies show that both methoxyethanol and ethoxyethanol have adverse effects on male fertility and cause developmental defects in the seminal quality and sperm parameters [33, 34]. (Fig. 1)

Goldstone reported that in 35 workers who worked in chemical production factories, the bisphenol A (BPA) in urine test was detected. Seminal quality in workers was significantly decreased [30]. In another study, Ianos et al. in 2018 reported in patients with impaired seminal quality after a urinary test, some metabolites of ethoxy-acetic acid (EAA) were detectable [35]. In another study, Ianos et al. in 2018 reported in patients with impaired seminal quality after a urinary test, some metabolites of ethoxy-acetic acid (EAA) were detectable (36). Research showed ethoxyaceticacid in urine is associated with exposure to chemical agents in paint products industries [37, 38].

In 2016, it was found that the risk of infertility was high in men who work in pesticide production factories. They reported low sperm concentration and high abnormal sperm morphologically in workers in pesticide production factories compared to workers in factories with no chemical exposure [39].

Many substances are used in the pesticide production industries, and the most important toxic substance for humans is Dibromochloropropane (DBCP) [30]. This substance can cause permanent azoospermia (zero sperm on seminal fluid). One-third of men with DBCP exposure suffer from azoospermia, and it was confirmed if they change their job, after about 4 years, they may improve slightly [40].

Several studies reported that exposure to some chemical agents, including dibromochloropropane, ethylene dibromide, and chlordecone, negatively affected seminal quality [41, 42].

In a study by SHAH and colleagues, they assessed fertility parameters in several different industrial workers. Their results showed in workers who worked in melting and furnace parts; sperm parameters were significantly lower than workers in textile chemical factories. So they concluded working in high-temperature places for elongated time is worse than textile chemical workers for male fertility [43].

Ethylene glycol-based materials were used many times in the industrial part. In a study, Cherry and colleagues showed a decrease in sperm concentration and motility in workers who worked in glycol ethers used manufactories 90 days before sperm analysis [44].

Carbon Disulfide is a chemical material that uses as a solvent in chemical industries. Guo et al. assessed 76 workers with exposure to Carbon Disulfide and compared with the non-exposed control group. Their results showed that working with Carbon Disulfide can create several defects in sperm parameters and sexual hormones [45].

Plastic industries widely use chemical products, and the workers in the plastic factory face with plastic chemical exposure daily. Several case-control studies reported sperm parameters, especially count and motility impaired in workers of plastic factories [36, 46, 47]. In a review paper published in 2018, researchers confirmed the negative effects of chemical exposure on sperm parameters of workers in plastic production factories [48]. One of the main materials used widely in reinforced plastic factories, polyesters production, and artificial rubbers is styrene [49]. Ianos et al. in 2018 in their study reported sperm concentration in workers who were exposed to styrene in the reinforced plastics industry was significantly low [31].

One of the main chemical materials for glues, varnishes and rubber cement production is acetone. Jelnes, in a study, evaluated sperm parameters in 25 workers exposed to acetone in the plastic factory and compared it with 46 fertile men as a control. The results showed seminal volume and sperm count not having significant differences between the two groups. Still, sperm motility, sperm normal morphology, and sperm viability significantly decreased in workers in comparison with the control group. Sperm head defects in morphological assessment were considerable, and the author concluded that the higher rate of abnormal sperms was the infertility cause in plastic factory workers [50].

Titanium dioxide (Tio2) is a chemical material utilized in some factories including automobile and cosmetic production factories. Danafar and colleagues in 2021 found Tio2 is harmful to the male reproductive system. They reported Tio2 exposure was a main parameter to decrease sperm parameters, especially sperm count and viability [51].

An important part of toxicity and male infertility may be related to toxic substances such as lead. The effects of lead on reproduction are multifaceted

and involve multiple pathways, many of which are not yet fully understood. For example, it is still unclear whether male reproductive problems are influenced by the effect of lead on sex hormones, or is due to the direct effect of lead on the sex glands, or both? [52]. Lead is another harmful chemical material for the human body [53]. In a study, several factories that used lead in main materials confirmed and noted glazed ceramics factories, cosmetics and industrial emissions, paint production, and lamp manufacturing factory [54]. Lead is used in lead acid battery factories, and workers in these factories are exposed to high lead levels daily. In a study, Naha et al. evaluated the sperm parameters in 80 lead acid battery factory workers and compared them with 40 control cases. The results of their study showed sperm parameters defected in lead acid battery factory workers specially abnormal sperm morphology increased significantly compared to control group [55]. (Table 1)

Farmers: Farmers and agriculture/farm workers are mainly exposed to chemical materials using pesticides [56]. Exposure to pesticides can occur in several ways, such as during transportation, mixing, pesticide application, maintenance, and cleaning of spraying equipment. The important factors about the level of exposure to pesticides included type of activity (such as using poisons, mixing), method of use (such as backpack, hand spray, speed sprayer), use of personal protective equipment (such as gloves, masks, boots or clothing) and personal hygiene and work habits (such as changing clothes or showering after work) [57, 58]. (Fig 1)

In developing countries, the use of pesticides is not selective. According to some studies, within the last 21 years, the average number of sperm in men has decreased and environmental toxins, especially chemicals, are considered the main cause [59]. Pesticides such as organochlorines, organophosphorus, carbamates, pyrethroids, and other pesticides used in agriculture impair sperm production directly by damaging testicular cells or indirectly by disrupting the hormonal regulation of spermatogenesis [55, 56].

Swan et al. in 2003 demonstrated that three chemicals in plant pesticides reduce sperm production, sperm count, sperm motility, and sperm normal morphology. They reported diazinon (to combat insects) and two herbicides called alachlor and atrazine were found in large quantities in the urine samples of men whose sperm count was lower than normal. Also, the sperm motility and normal morphology in these men were lower than normal. They concluded the 3 chemicals could elevate the risk of immotile sperm and abnormal morphology 30 times [60].

In 2010, Hossain et al., evaluated pesticide exposure and its effects on the seminal quality of farm workers. Their study showed that the rate of abnormal semen quality increased in agricultural workers after pesticide exposure [61]. Recently in a study, Knapke et al. reported poor semen quality in farmworkers. They confirmed pesticide exposure was the cause of low semen quality in the farmworkers [62].

Mehrpour and his colleagues in 2014 reported that organophosphoruses could decrease sperm count, motility, and viability. They concluded self-protection during pesticide use in farmers is essential to fertility preservation in men [63]. In 2012, Ben Abdallah et al., showed that dimethoate as an organophosphorus pesticide may cause a decrease in sperm parameters, especially sperm motility and viability [64]. Hanke et al., in their published paper, reported in papaya farmers who used Ethylene dibromide (EDB), sperm parameters (count motility and normal morphology) significantly decreased [65].

Henderson and his colleagues assessed the seminal sample of infertile men. The results of this study showed in farmers, the sperm concentration, rate of motile sperm, and normal morphology were significantly lower than in other infertile men. They concluded that exposure to pesticides and occupational toxins is responsible for sperm defects in farmers [66].

Sadighi and his colleagues investigated sperm parameters in 500 Iranian men and reported that abnormal sperm parameters (count and motility) were higher in farmers than in other jobs [67].

Recently plastic greenhouses extended, and farmers in these greenhouses (closed places) were exposed to pesticides at high levels. In 2021, Fucic et al., reported sperm parameters spatially that sperm motility decreased in greenhouses workers. They also confirmed duration of staying in plastic greenhouses was a main factor for sperm defects [18]. (Table 1)

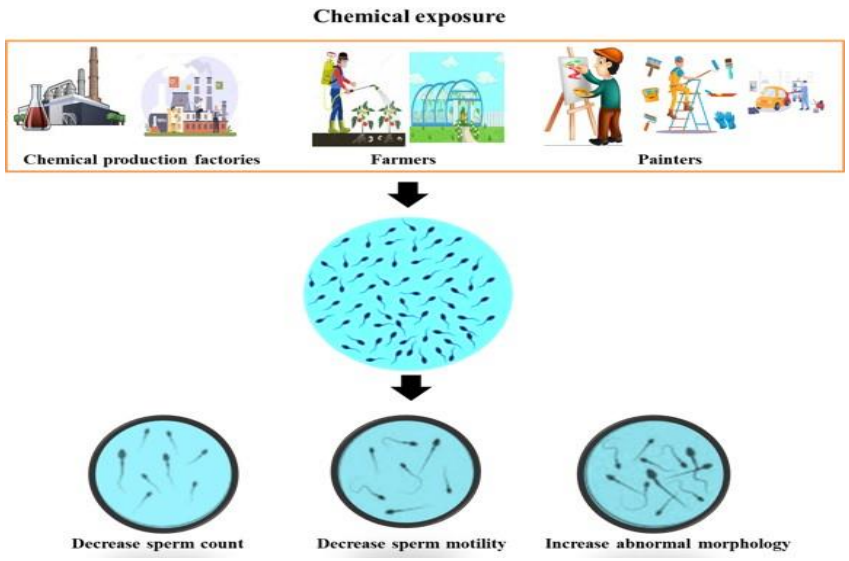

Fig.1. Schematic picture for effects of chemical exposure on sperm parameters

Painters: Painters of different types (art, building painting, automobile painting) are an occupational group with high risk to long-term exposure to petroleum solvents, alcohols, esters and glycol ethers, benzene, toluene, xylene, and organic solvents. All of these are harmful to human body [68]. Exposure to the solvents, colors, and painting materials may lead to low sperm count [69]. Chemical painting materials may be transferee form the blood–testis barrier and create defects in sperm production and maturity [70, 71]. (Fig 1)

Hosni and colleagues, in 2013 in their study assessed the hormonal levels and sperm parameters based on the different levels of lead in the blood of 27 infertile building painters. Their study showed that sperm parameters have a significant negative relationship with lead levels, especially sperm count and motility. They also reported that hormone levels were not significantly changed at different lead levels, although testosterone levels were significantly elevated [72]. In another study, Irnandi et al. in 2021 examined the seminal fluid of 15 men working in an automobile painting and 12 office workers as a control group. Their results showed defects in sperm quality of automobile painters were higher than the control group [73]. Kenkel and his colleagues 2001 investigated 2054 infertile men based on six occupational groups (farmer, forester, miner, welder, painter, and industry worker). Their results showed that sperm concentration and count significantly decreased in painters. Also they found sperm parameters spatially sperm count significantly lower than the normal reference [74]. In a study, researcher evaluated the sperm parameters of 50 painters working in aircraft maintenance and compared them with 8 men without exposure to aircraft maintenance chemicals. The results showed low sperm motility in painter workers [75]. (Table 1)

Discussion

In this literature review we tried to assess new and important studies about chemical effects on sperm parameters as a main factor in assessing male fertility potential. 3 main chemical exposure occupational (Chemical Production Factories, farmer and painters) assessed. Although there may be many factories whose chemicals are harmful to male reproduction, in the present study, we tried to examine the most important ones. Also several pesticides may be harmful for male fertility but we aggregate the main of all. According to the findings of the studies, variations in the results are comprehensible. For verification, the next important step in research is to identify the basic factors that may justify these harmful effects. Specifically, chemical exposure may play an important exacerbating role in human physiological systems. Hence, investigating the possible role of different types of chemical exposures (such as industrial and environmental) in developing male fertility may provide the effecting mechanisms. Because existing research suggests that the relationship between industrial life and infertility development is probably reciprocal. We think, the difference between studies may be due to variation in the study population from several nationalities, variants in genetic conditions, lifestyle, and susceptibility of reproductive.

Conclusion

Results of the studies are controversial, and it seems epidemiological investigations cannot approve the harmful effects of some occupational

chemical exposure on fertility potential and sperm parameters. During interpreting the results of the studies, it is important to emphasize that the type of chemical mixtures, duration of exposure (chronic exposure to different levels), and number of compounds, physiological and psychological conditions can play a key role.

Acknowledgement

The Authors would like to thank Miss Monavar Naderi for helpful online search suggestions.

Conflict of interest: None declared.

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