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Occupational exposure to pesticides and consequences on male semen and fertility: A review

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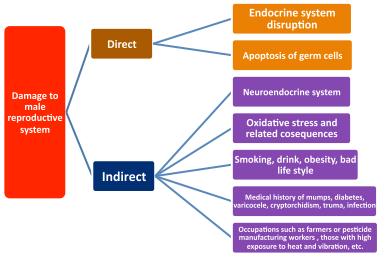
HIGHLIGHTS

- Exposure to pesticides induces reproductive hormonal changes.
- Sperm's DNA damage may occur in exposure to pesticides.
- DDT and its metabolites have estrogenic effects on males.
- Well-designed long-term studies are needed to explore full effects.

GRAPHICAL ABSTRACT



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ABSTRACT

Exposure to pesticides affects many body organs including reproductive system. Disorder of the reproductive system leads to infertility and therefore has been in the center of attention within the recent decades.

Pesticides are one of the compounds that might reduce the semen quality in the exposed workers according to current knowledge. Although many underlying mechanisms have been proposed, the mechanisms of action are not clarified yet. The object of the present review was to criticize all the results of studies which evaluated the pesticide effects on male reproductive system. Results indicate that semen changes are multifactorial in the workers exposed to pesticides as there are numerous factors affecting sperm quality in occupational exposures. Majority of pesticides including organophosphoruses affect the male reproductive system by mechanisms such as reduction of sperm density and motility, inhibition of spermatogenesis, reduction of testis weights, reduction of sperm counts, motility, viability and density, and inducing sperm DNA damage, and increasing abnormal sperm morphology. Reduced weight of testes, epididymis, seminal vesicle, and ventral prostate, seminiferous tubule degeneration, change in plasma levels of testosterone, follicle-stimulating hormone (FSH), and luteinizing hormone (LH), decreased level and activity of the antioxidant enzymes in testes, and inhibited testicular steroidogenesis are other possible mechanisms. Moreover, DDT and its metabolites have estrogenic effects on males. Although effect of pesticides on sperm quality is undeniable, well-designed long-term studies are needed to elucidate all the possible affecting variables such as socioeconomic, cultural, nutritional, occupational, physical, and clinical characteristics alongside pesticides.

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1. Introduction

1.1. Occupational hazard

Agriculture is a source of economic income especially in the developing countries. Farm workers may have contact with many substances with potential hazards, of the most common of which, are pesticides and particularly the organophosphorus (OP) compounds (Mostafalou and Abdollahi, 2013a,b).

Of the known causes of infertility are occupational exposures to harmful environmental factors (Table 1). Since many of these potential hazards exist in the environment, occupational exposures are not easy to be proved. However, the decreased fertility rate in certain occupations is much more significant than what is expected among the general population (Ashiru and Odusanya, 2009). Unfortunately, chronic or low-level exposures are not defined and this makes it difficult to determine different classes of exposures in the studies (Peiris-John and Wickremasinghe, 2008). Peiris-John and Wickremasinghe (2008) tried to determine whether exposure to OPs, at levels lower than that result in clinical manifestations of acute OP poisoning, leads to any adverse impact on fertility, growth and development. They suggested that OP exposure has a greater impact on fetal and infant growth and development than on adults when exposed to the same concentrations of pesticides and meanwhile raised concerns regarding exposure levels currently considered as safe level for human reproductive function.

Occupational exposure occurs while mixing, loading, spraying, and assessment of the pesticides (Shadnia et al., 2005; Mekonnen and Ejigu, 2005). There are different types of occupational hazards affecting reproductive organs in both males and females (Table 1). But, male reproductive activity is highly sensitive to many man-made chemicals and physical agents produced by agricultural and industrial activities (Ashiru and Odusanya, 2009).

Female or male infertility is the reason for involuntary sterility in 39% and 20% of the cases, respectively; in 26% of the cases, the reason is found in both men and women. The clinicians cannot identify the cause of infertility in 15% of the cases (idiopathic sterility) (Winker and Rüdiger, 2006). Infertility is not limited to Western countries; it is a global phenomenon involving developing countries, as well (Clementi et al., 2008). Subfertility is another phenomenon regarded to be idiopathic in most men (Bretveld et al., 2007) and can be influenced by several factors such as lifestyle, occupational exposure, environmental exposure, and other conditions listed in Table 1. Regarding the possibility of occupational exposure to pesticides, some protection guidelines have been described in details but they are not always adhered (Table 2).

Table 1
Factors that can influence semen quality.

Life style	Smoking, drinking alcohol, obesity (Mendiola et al., 2009), long exposure to microwave (Sheiner et al., 2003)
Medical history	Mumps, diabetes, mellitus, varicosele, cryptorchidism, history of testicular trauma (Winker and Rüdiger, 2006), genital infection (Feki et al., 2009)
Drug history	Cimetidine, spironolactone, nitrofurantoin, sulfasalazine, erythromycin, tetracycline, anabolic steroids, chemotherapeutic agent, alpha blockers, methyldopa, respridone (Sheiner et al., 2003)
Environmental factors	Type of jobs: farmers, mixers, loaders, applicators who are in danger of exposure to the toxin, heat, and vibration or may be sitting for long periods (Vaziri et al., 2011) Noise, genital heat stress, psychological stress, duration of working, distance from the house to the farm field (Tuc et al., 2007)
Physical factors	Physical pressure and load on the pelvic organs (Sheiner et al., 2003)
Occupational chemicals/metals	Lead, cadmium, chromium, copper, mercury (Mostafalou and Abdollahi, 2013a, 2013b) Pesticide (Clementi et al., 2008), solvents, estrogens (Winker and Rüdiger, 2006)
Climate weather	During summer months there is a decline in sperm density and sperm count (Sifakis et al., 2011)
Psychological factors	The limited attention to the topic of psychological stresses at work is partially due to the difficulty in separating between sources of emotional stress at work and outside the work. One of the common causes of poor fertility-being investigated recently is stress at the workplace (Sheiner et al., 2003)

1.2. Scope of the pesticide's use

A pesticide is defined as "any substance or combination of substances used to prevent or eradicate unwanted insects including vectors of diseases in human-beings and animals, weeds, fungi, or animals in order to enhance food production and help production processing, storage, transport, or marketing of the food and agricultural commodities" (Abdollahi et al., 2004; Clementi et al., 2008; Shadnia et al., 2005; Sifakis et al., 2011). Pesticides act as endocrine disrupting chemicals (EDCs). The EDC is defined by US environmental protection agency (EPA) as "an exogenous agent that is potentially capable of synthesis, secretion, transport, binding, action, or elimination of the natural hormones responsible for the maintenance of homeostasis, reproduction, and developmental processes in the body" (Sifakis et al., 2011).

Table 2
Approaches to mitigate pesticide's exposure to agriculture workers.

Personal protective equipment
Glove
Boots
Apron
Coveralls
Glasses
Face-shield
Waterproof garment
Respirators
Enclosed tractor covered-cabs during pesticide/herbicide application instead of manual handling of sprayers
Precaution
Pesticides should not be used for cosmetic lawn care
Safety clothes +responsible employee for laundry
Routine washing hands/face/neck before breakfast and lunch
Daily shower at the end of daily shift work
Separation of dwellings and work place to decrease exposing workers' families and neighbors (Ashiru and Odusanya, 2009)
Use of lower-risk pesticides
Use of alternative methods of pest control such as optimal crop rotation
Training
Workers, especially all newly-hired ones, should receive adequate training
Training should be conducted about personal hygiene/proper use of equipment/alternative pest control methods/and adverse effects of pesticide exposure
Safety instructions and application techniques, as well as information regarding the inherent toxicity of chemicals, should be in local language or understandable symbols for mixing and application of pesticides in the package
Guidance on the proper use of pesticides should be made available from suppliers and academic institutions
Employing people with indigenous language as organizational leaders and health workers should facilitate the occupational safety training system (Samples et al., 2009)
In UK, the government now requires more positive reassurance before specific use is permitted (Coggon, 2002)
Legislation
Protecting employees from occupational toxins where evidence suggests that workers' ability to have healthy children may be jeopardized
Periodic health surveillance should be available for all workers exposed to the pesticides

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