Guide to Men's Reproductive Health in the Mining Workplace

A Laurentian University &
Workplace Safety North Initiative

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Introduction

There is accumulating evidence that some workplace environments expose workers to hazards that potentially cause reproductive health problems, many of which are preventable. In the mining industry workers are exposed to a host of potential hazards and some of those hazards may impact upon their reproductive or sexual health. Specific concerns tend to vary by age, with younger workers generally focused on fertility issues that may impact upon their ability to start a family and older workers being more concerned about sexual health. Regardless of age or presenting concern, miners experiencing fertility problems or other sexual health issues may benefit from a formal hazard assessment of their job to determine if occupational exposures are contributing to or causing their reproductive health problem.

What is a reproductive hazard?

A hazard is an agent that has the potential to cause harm to a person. A 'reproductive' hazard is an agent that can adversely affect the reproductive health of women and men and/or negatively impact the growth and development of a fetus. Examples of reproductive problems linked to hazardous agents include: reduced fertility, by harming sperm or ova; miscarriage, if an embryo is damaged (toxic agents can be transferred by sperm); or disruption of hormonal pathways involved in reproduction and sexual function (e.g. testosterone decline). Hazardous agents are present in both non-occupational and occupational settings.

Objectives of this Guide

This Guide has two primary objectives. The first objective is to provide information about the health effects of workplace hazards in the mining industry on male reproductive health. The second objective is to provide information about safety measures and controls that may help inform and therefore prevent or minimize exposure to reproductive hazards. However, it should be noted that it is the employer's responsibility to identify and implement controls for exposures. In many cases, simple measures including minor restructuring of the work environment or work schedule and use of personal protective equipment can ensure the safety of the worker and his future offspring. Effective prevention measures for a given worker vary depending on individual circumstances; therefore, all decisions should be made on a case-by-case basis. The information contained in this Guide can be used to help inform the decision making process.

This Guide serves as an information resource for human resource managers, occupational therapists, industrial hygienists, employers, supervisors and workers. The Guide is intended to be used in conjunction with other resources such as confidential interviews with trained health and safety professionals including nurses and physicians. The material contained in this Guide is for information and reference purposes only and not intended as legal or professional advice. The adoption of practices described in this Guide may not meet the needs, requirements or obligations of individual workplaces.

This Guide has not been designed to address occupational safety matters related to conception or female reproductive biology. See the companion piece: Guide to Healthy Pregnancies in the Mining Workplace (http://www.crosh.ca/publications.html).

How to use this Guide

In this Guide, hazards in the mining workplace are listed under three major subheadings: physical agents (noise, vibration, heat, radiation); chemical agents (gases, dusts, mists, vapors, fumes) and other factors (ergonomic factors, scheduling and workplace stress). Hazardous agents are identified in the first column. Examples of where the agent is encountered are listed in the second column. In the third column, the risk to the worker and, when indicated, the developing fetus, is described. The fourth column provides some examples of safety measures and controls that may help to prevent or minimize the worker's exposure to the agent. When available, recommended exposure limits as defined by the American Conference of Governmental Hygienists (ACGIH) are listed, including the agents "STEL"(short-term exposure limit) and "TWA"(time-weighted average limit), as per Ontario Regulation 490/09 and 833 and have not been proven to specifically protect against reproductive health hazards.

The hazardous agents listed in this Guide have been selected because they are the most commonly encountered reproductive hazards in the mining workplace; however, it is important to note that the list of agents in the Guide is not all-inclusive. For example, biological agents that affect reproductive health such as viruses, fungi and mould are not included because, while these hazards may exist in mining, exposure is not thought to be increased in this workplace compared to other industries or non-occupational settings.

There remains scientific uncertainty about what regulatory agencies should do to protect the reproductive health of workers. For instance, dose-response information is lacking for the majority of reproductive hazards. This is because most of our current knowledge comes from animal studies; there are only a limited number of human studies examining occupational reproductive hazards. Given the current scientific uncertainty, most regulatory agencies recommend exposure levels be kept as low as reasonably possible. Every effort should be made by both the employer and the worker to minimize risk of exposure.

A Man's Role in Reproduction

Because the emphasis of a healthy pregnancy traditionally focuses on the woman's role, the potential for problems resulting from the father's exposure to a reproductive hazard is often overlooked or unknown. On the basis of current understanding, reproductive health problems in men are thought to occur via five main mechanisms:

1. Gene/chromosomal mutation of the sperm;
2. Hormonal changes (e.g. reduced testosterone);
3. Reduction in sperm numbers;
4. Disturbance of sperm shape or motility; and
5. Erectile dysfunction.

Exposure to reproductive hazards in the workplace generally impact male reproductive function through one or more of these mechanisms ultimately resulting in infertility or unsuccessful pregnancy. Examples of such hazards include vibration, heat, chemicals (arsenic, lead), shift scheduling and occupational stress. It is important for men to have access to information about potential workplace hazards and prevention to prevent exposure and preserve their reproductive health

How are Sperm Made?

Sperm are the male reproductive cells that are transported in semen. Sperm production, known as 'spermatogenesis' occurs in the testicles during an approximate 70-day cycle. Spermatogenesis is constantly occurring over the three-month cycle. For hazardous exposures that directly affect spermatogenesis (for example, heat stress), the effect is usually temporary and reversible, with normal sperm production resuming over the 3 months following removal from exposure. Other hazardous agents cause longer-term effects on reproductive function, either because they remain in the body after removal from exposure (for example, lead) or because the agent directly damages the testicles (for example, hexavalent chromium which may cause testicular atrophy).

In addition to sperm production, the testicles also produce the hormone testosterone. Testosterone is an essential hormone that influences sperm production, reproductive tissue development, sexual drive and sexual performance. Some hazardous agents, for example lead, manganese and mercury, have been demonstrated to alter hormone levels thereby impacting reproductive function and fertility.

Disclaimer

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PHYSICAL HAZARDS

PHYSICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Extremes of Heat	Summer mine work, depth, working in any hot and/or humid environment.	**Reproduction:** • Testicular function is temperature dependent and requires a temperature 2°C to 4°C below core body temperature[1], [3] Elevated scrotal temperature is referred to as scrotal hyperthermia • Scrotal hyperthermia causes abnormal spermatogenesis[1] ,[2], [3], [4], [5] resulting in decreased sperm count and impaired motility and/or morphology [6], [7], [8], [9], [10], [11] , [12], [13], [14] which can result in adverse pregnancy outcomes [12] • Spermatogenesis requires about 70 days, so the effects of heat may be noted 2-3 months after exposure [29] **Sexual function:** • Insufficient data	Consult NIOSH Guidelines on monitoring and controlling heat exposures in the workplace.[1], [3] Avoid prolonged sitting / encourage tasks that allow altering seated position frequently (sit in same position for < 28 minutes at a time).[15] Note: despite normal and constant core body temperatures (around 37° C), normal scrotal temperatures (34-36°C) can increase by 2.2 ^{0}C with prolonged sitting. [17] Avoid prolonged driving for more than two hours.[17] Avoid laptop usage on lap.[15],[18] Encourage task rotation / switching machines over the course of the shift to facilitate different body postures to avoid scrotal heat stress. Remove worker from the hot environment to facilitate recovery of testicular function.[3] Recovery of testicular function is noted after 4-11 weeks but can take 6 months after exposure to extreme heat ceases. [1] In general, the more prolonged the elevation in testicular temperature the greater the detrimental effect on spermatogenesis.[19], [9], [20]

PHYSICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Ionizing Radiation	Radiation in mines, especially in mines where thorium or uranium is found. Radon and Radon daughters: No known effects of Radon exposure on male fertility	**Reproduction:** • Decreased sperm count and/or temporary inability to produce sperm [1], [3], [21], [14] • In some cases, permanent sterility [22], [1], [23], [24], [8], [10] ,[25], [13], [11], [26], [27] ,[12], [3] • Damage to testicular germ cells [1] **Sexual function:** • Insufficient data **Fetus:** • Paternal doses of ≥ 10 mSv (1 rem) in 6 months before conception or total preconception doses ≥ 100 mSv (10 rem) associated with 6-8 fold increased risk of leukemia in offspring [1], [3]	The annual worker exposure limit for nuclear energy workers is 50 mSv (5 rem).[3] For other workers (ex. workers performing non-destructive testing, servicing nuclear gauges or operating X-ray equipment), the annual exposure limit is 1 mSv for nuclear sources or 5 mSv from all sources. Therefore, keep exposure limits 'as low as reasonably achievable' [28], [29] by monitoring exposure time and distance from hazard. Sperm banking prior to exposure is suggested. Time-to-recovery of testicular function is dose-dependent and may vary between 6-24 months.[1], [3]Delay conception for 3-6 months to ensure that the fertilizing sperm was not produced from a germ cell exposed to radiation.[1]
Noise	Vehicular machinery, power tools, compressed air discharge, ventilation fans.	**Reproduction:** • No direct effects of noise on male fertility are reported to date, therefore no impact on length of time to conception[30] • In humans, prolonged exposure to noise >80 dBA increases levels of stress hormones[31] which can in turn be a risk factor for infertility by negatively impacting sperm parameters[32] **Sexual function:** • Increased stress and suppression of testosterone production[33] supported by animal studies indicating that chronic noise exposure in mice and rats linked to decreased testosterone levels[34],[35] • Disruption in hormonal pathway may impact sexual function and sex drive	Avoid >8 hours exposure or equivalent exposure, to noise greater than 8 dBA.[36], [37] Although direct effects of noise on fertility have not been proven, it is reasonable to suggest that hormone levels may be altered in some men by stress. Therefore, educating the workers regarding the risks of occupational exposure to excessive noise [37] and wearing proper protective equipment during shift are practical, preventative strategies.[3], [37]

PHYSICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Vibration	Vehicle operation, equipment, vibrating floors near heavy equipment operations, vibrating platforms.	**Reproduction:** • Significant reduction in spermatogenesis reported in men occupationally exposed to vibration[38]; supported by animal studies where male rodents exposed to 4 hours of vibration for 125 consecutive days at 5.07 m/sec/sec showed reduced spermatogenesis[3] **Sexual Function:** • Erectile dysfunction due to vascular effects from seat compression and vibration reported in a non-occupational setting[39] • Single case study of 'Penile Raynauds' in a worker with white finger and white toe[40] • Androgen hormone levels may increase from whole-body vibration but beneficial effects from this increase are not reported[41]	Keep vibration at acceptable workplace levels. Lower and upper limits of the 8 hr health guidance caution zone are 0.45 m/s^2 and 0.90 m/s^2 respectively for frequency-weighted r.m.s. acceleration values.[42] Lower and upper limits of the 8 hr health guidance caution zone are 8.5 $m/s^{1.75}$ and 17 $m/s^{1.75}$ respectively for the vibration dose values.[32] Avoid whole body vibration above the limit value of frequency-weighted r.m.s. acceleration of 1.15 m/s^2 or vibration dose value of 21 $m/s.^{1.75}$ [43] It is unclear whether the negative effects of vibration are due to the direct effects of vibration or due to the indirect effects of the vibration-induced increase in temperature. Therefore, see also "Actions to Avoid" for " Extremes of Heat" above.

CHEMICAL HAZARDS

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Aluminum	May be encountered during bauxite mining or aluminum refining or processing, welding. Also maintenance work such as grinding and machining (fabrication).	**Reproduction:** • Deterioration in sperm motility • Animal (rodent) studies decreased testicular and epididymal weight, reduced sperm counts and fecundity at doses of 100-200 mg/kg/day[3], [45] **Sexual function:** • Insufficient data **Fetus:** • Neurobehavioural abnormalities found in offspring[3]	TWA[46], [47]: 1 mg/m^3 (respirable fraction)
Arsenic	Product of mechanical extraction of ores or minerals, byproduct of smelting lead, copper, and zinc ores.	**Reproduction:** • High doses associated with testicular damage[3], [48] • No available studies of fertility in humans[49], [50], [51]but animal studies report impairment of spermatogenesis[51] **Sexual Function:** • Insufficient data	TWA [46], [47]: 0.01mg/m^3 STEL[46], [47]: 0.05 mg/m^3
Beryllium	Control rods in nuclear reactors, sheet metal or wire welding. Mining or processing of rare earth element ores; recycling of metals.	**Reproduction:** • Toxic to testicular structures and associated with abnormal sperm morphology according to animal studies[3] • **Sexual function:** • Insufficient data	TWA [46], [47]: 0.05 µg/m^3 STEL[46], [47]: 0.01 mg/m^3

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Cadmium	Product of mechanical extraction of ores or minerals, byproduct of smelting lead, copper, and zinc ores. Cigarette smoking is a source of cadmium exposure.	**Reproduction:** • Decreased levels of fertility at blood levels <10 µg/L and reduced sperm motility and/or morphology[52] ,[53], [54], [11], [51], [55], [56] • Known to affect male reproduction via various mechanisms (affects prostate)[3], [57], [5], [58], [59], [14] **Animal Studies:** • Selective testicular damage at doses of 1.1-2.2 mg/kg[1] **Sexual function:** • Insufficient data	TWA[46] ,[47]: 0.002 mg/m^3(Respirable fraction) 0.01 mg/m^3
Carbon Monoxide	Diesel exhaust, iron and steel foundries, welding, forklift operations, blasting gases, improper ventilation. Cigarette smoking is a source of carbon monoxide exposure.	**Reproduction:** • No known direct effect on male reproductive health • **Sexual function:** • No known direct effect on male sexual function	TWA[46], [47]: 25 ppm
Chromium (metal/ inorganic) Hexavalent form The trivalent form, in trace amounts, is an essential nutrient.	Inhalation exposure hazard during stainless steel welding, corrosion inhibitor.	**Reproduction:** • Testicular atrophy [32] • Degree of damage proportional to dose [51] • Decreased levels of fertility, reduced sperm motility/morphology, decreased testosterone levels and increased levels of follicle-stimulating hormone (animal studies)[3], [54], [11], [51], [73] **Sexual Function:** • Insufficient data	TWA[46], [47] Metal and Cr III compounds: 0.5 mg/m^3 Water- soluble Cr VI compounds: 0.05 mg/m^3 Insoluble Cr VI compounds: 0.01 mg/m^3

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Copper Copper is an essential nutrient, but is toxic at high doses.	Used in alloys and in electroplating.	**Reproduction:** • Toxic to sperm when in direct contact, decreased sperm count, abnormal sperm[3] **Sexual Function:** • Insufficient data	TWA[46], [47] Fume: 0.2 mg/m^3 Dust & mists: 1 mg/m^3
Fire by-products (i.e. hydrogen cyanide, hydrocarbons)	Mine fire.	**Reproduction:** • Negative effects on spermatogenesis and male fertility have been observed in firefighters. This may be due to a host of toxicants in residential or industrial fires. It is possible some of the same toxicants may be present in mine fires (e.g. PAHs)[60] **Sexual function:** • Insufficient data	Avoid smoke inhalation. Use of self-contained breathing apparatus (SCBA) to prevent fire smoke exposure in responders to fire events.
Hydrogen Sulfide	Iron smelters, blast emissions. Also a decomposition gas (sewage handling).	**Reproduction:** • No known direct effect on male reproductive health **Sexual function:** • No known direct effect on male sexual function	TWA[61]: 10 ppm STEL[61]: 15 ppm

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Lead (elemental/ inorganic)	Product of mechanical extraction of ores or minerals, by-product of smelting lead, copper and zinc ores.	**Reproduction:** • Testicular toxicity leading to decreased levels of fertility and reduced sperm count/motility[62], [52], [63], [23], [12], [24] ,[3], [56], [16], [53], [32], [13], [10], [51], [11], [26], [14], [64], [65], [5], [59] • Blood levels ≥40-50 µg/dl linked to changes in germ cell structure and function leading to abnormal sperm[1], [12], [66], [56], [54],[68], [69] **Sexual function:** • Reductions in testosterone levels[8] **Fetus:** • Male preconception blood levels greater than 30 µg/dl associated with increased risk of spontaneous abortion in female partners[1], [12], [3], [56] • Birth defects noted in children where paternal exposure was 2 to 4 times higher than normal. • Perinatal death twice as common, increased incidence of cleft lip from paternal exposure[70]	TWA[46], [47]: Elemental Lead: 0.05 mg/m^3 Tetraethyl lead: 0.10 mg/m^3 STEL[46], [47]: Tetraethyl lead: 0.30 mg/m^3 If not already regularly screening for blood lead levels, as per safety standards (regulation 490), screen during the preconception period.[1]
Manganese (elemental/ organic) Manganese is an essential trace nutrient, but is toxic at high doses.	Used in steel production, as chemical compounds, and in welding rods.	**Reproduction:** • Decreased fertility[52], [6], [5], [11] **Sexual function:** • Suspected to affect libido[6], [12]	TWA[46], [47]: Inorganic forms: 0.2 mg/m^3

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Mercury	Used in instruments and older milling equipment. Electricians handling energy-saving light bulbs containing mercury.	**Reproduction:** • Interferes with male reproductive function/spermatogenesis[52], [24], [5], [54], [59], [14] • Organic mercury exposure for over 10 years correlated with oligospermia, teratospermia, asthenospermia, and reduced libido[12] • Affects fertility and is toxic in rodents (animal studies) **Sexual function:** • Insufficient data **Fetus:** • Urinary levels greater than 250nmol/L male workers associated with a 2-fold risk of spontaneous abortion in female partners[71], [1], [3]	If exposure is known to occur, discuss with a health care professional and delay attempts at conception for longer than 3 months (i.e. Related to time required for sperm turn-over).[71] TWA[46] ,[47]: Alkyl compounds (as Hg): 0.01mg/m^3 All forms except alkyl (as Hg): 0.025 mg/m^3 STEL[46], [47]: Alkyl compounds (as Hg): 0.03 mg/m^3
Mono-Ammonium Phosphate and Sodium Alkyl Sulfate	ABC, Dry Chemical, fire extinguishers.	**Reproduction:** • No known direct effect on male reproductive health **Sexual function:** • No known direct effect on male sexual function	Due to the general safety and health risks of using a fire extinguisher of this type (i.e. hypoxia), use with caution.[72]
Nickel	Used in mining and processing of nickel ores and alloys such as stainless steel and nickel carbonyl produced during nickel refining.	**Reproduction:** • Decreased fertility[16] and decline in semen parameters from nickel produced by welding fumes[3], [73] **Sexual function:** • Insufficient data	TWA[46], [47]: Elemental/metal: 1 mg/m^3 Insoluble compounds: 0.2 mg/m^3 Soluble compounds: 0.1 mg/m^3 Nickel subsulfide: 0.1 mg/m^3 Nickel carbonyl: 0.05 ppm

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Nitrates, Nitrites, and Organic Nitro Compounds	Explosives, blasting rock and waste water.	**Reproduction:** • Toluenediamine and dinitrotoluene are on NIOSH's list of male reproductive hazards[3] • Dinitrobenzene and dinitrotoluene are associated with testicular toxicity[21] • Animal studies (male rats): decreased epididymal sperm reserves (63% reduction in animals treated with 0.2% dinitrotoluene-highest dose group)[3], [74] **Sexual function:** • Insufficient data	TWA[46], [47]: Dinitrotoluene: 0.2 mg/m^3 Nitrobenzene: 1 ppm Nitroglycerin: 0.05 ppm Trinitrotoluene: 0.1 mg/m^3 or 0.01 ppm Nitrotoluene (all isomers): 2 ppm STEL[46], [47]: Trinitrotoluene: 0.02 ppm or 0.2 mg/m^3
Nitrogen Oxides (NOx): Nitrogen Dioxide (NO_2) and Nitric Oxide (NO)	Diesel exhaust, blasting gases, welding. Cigarette smoking is a source of nitric oxide and one mechanism for reduced fertility in male smokers is via increased production of systemic NO concentrations.[75]	**Reproduction:** • Human sperm is rich in poly unsaturated fatty acids which are sensitive to oxygen induced damage. NOx gases produce free radicals and are thought to damage sperm through high levels via this mechanism. Occupational evidence for this is limited and conclusions are conflicting. • Airborne pollutants of nitrogen oxide and nitrogen dioxide linked to reduced sperm count[76] • NO decreases sperm motility and induces sperm toxicity *in vitro*.[77] • A study in hospital workers with mean NO exposure of <50 ppm found no sperm abnormalities.[78] • Two studies looking at NO_2 exposure in men found a small increase in spontaneous abortion and congenital malformations[79], [80] however, these studies are criticized for confounders (reviewed in Paul) or attributable to the duration of exposure (mean greater than 30hr/week) and levels of NO_2 well above the NIOSH TWA of 25 ppm. (continued next page…)	TWA[46], [47]: Nitric Oxide: 25 ppm or 45 mg/m^3 Nitrogen Dioxide: 3 ppm STEL[46], [47]: Nitrogen Dioxide: 5 ppm Maintaining levels below these standards should be sufficient protection.

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
		• Notably NO levels increase with cigarette smoke and is thought to be a mechanism for increased infertility in men who smoke. **Sexual function:** • No known direct effect on sexual function	
Particulate Matter (PM)	Diesel exhaust from machinery, rock dust.	**Reproduction:** • No known direct effect on male reproductive health, however, PM carrying multiple trace elements including heavy metals and polycyclic aromatic hydrocarbons (PAHs) can act as endocrine disruptors affecting both the hypothalamic pituitary axis and testicular spermatogenesis.[81] • They also have the potential for causing sperm alterations (DNA damage).[81] **Sexual function:** • PM in the respirable range (PM 2.5) can enhance atherosclerosis[82], [83], [84], [85] which can impair blood flow and therefore contribute to erectile dysfunction.[86], [87] • PM carrying multiple trace elements including heavy metals and polycyclic aromatic hydrocarbons (PAHs) can act as endocrine disruptors affecting both the hypothalamic pituitary axis and testicular spermatogenesis.[81]	TWA : total carbon 0.4 mg/m^3[88]

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Polycyclic Aromatic Hydrocarbons (PAHs)	Generated from incomplete combustion of organic material and fossil fuels and vehicle exhaust. Cigarette smoking is a source of PAHs.	**Reproduction:** • Associated with sperm DNA damage[89], [90], [91] and decreased sperm motility[92], [93] • In rodents, linked to testicular atrophy, hinders fertility and is associated with reduced sperm motility [3], [91], [93], [94] **Sexual function**: • Insufficient data **Fetus**: • Sperm DNA damage in the male germ line; major contributor to infertility and linked to an increased incidence of miscarriage and the appearance of various kinds of birth defects in the offspring[95], [96]	TWA [46], [47]: Keep exposure by all routes as low as possible. Educational workshop; review by worker of safety regulations to keep particulate matter levels at a minimum during shift, (because polycyclic aromatic carbons typically bind to fine particulate matter).
Selenium Selenium is an essential nutrient but potentially toxic at high doses.	Product of mechanical extraction of ores or minerals.	**Reproduction:** • Insufficient data. **Sexual function**: • Insufficient data	TWA[46], [47]: Selenium and compounds: 0.2 mg/m^3 Selenium hexafluoride: 0.025 ppm or 0.1 mg/m^3
Tellurium	Product of mechanical extraction of ores or minerals.	**Reproduction:** • Insufficient data **Sexual function:** • Insufficient data	TWA[46], [47]: Tellurium and compounds, as Te, excluding hydrogen telluride: 0.1 mg/m^3 Tellurium hexafluoride: 0.01 ppm or 0.1 mg/m^3

CHEMICAL HAZARD	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Thallium	Product of mechanical extraction of ores or minerals, smelting of lead and zinc ores.	**Reproduction:** • Chronic exposure linked to testicular dysfunction, reduced sperm motility[97] and altered sperm morphology in rodents[98] **Sexual function:** • Insufficient data	TWA[46], [47]: 0.02 mg/m^3 (inhalable fraction) NIOSH has recommended that 15 mg/m^3 of thallium be considered immediately dangerous to life and health.[99]
Uranium	Can be a naturally occurring chemical in mines.	**Reproduction:** • Human data insufficient, though has the potential to pose a radiation risk (see 'ionizing radiation' above). Daily exposure of uranyl acetate in drinking water for 64 days hinders male fertility and decreases sperm count in rodents[100], [3], [101] **Sexual function:** • Insufficient data	TWA[46], [47]: 0.2 mg/m^3 STEL[46], [47]: 0.6 mg/m^3
Vanadium Pentoxide	Used as an alloy, present in crude oil, used in some diesel exhaust catalysts, and catalysts for production of sulphuric acid.	**Reproduction**: • Human data insufficient • Linked to decreased sperm count and fertility rates, lower testosterone levels and prostate atrophy in rodents [3], [102] **Sexual function**: • Insufficient data	TWA[46], [47]: 0.05 mg/m^3
Zinc Chloride **Zinc Oxide** Zinc is an essential nutrient, but can be toxic at high doses.	Used as an alloy, as a metal coating and soldering flux and released when welding galvanized surfaces and during smelting of metal concentrates.	**Reproduction**: • No known health effects on human male reproductive health[48] **Sexual function**: • No known health effects on human male sexual health[48]	TWA[46], [47]: Zinc chloride fume: 1 mg/m^3 Zinc oxide: 2 mg/m^3 (Respirable fraction) STEL [46], [47]: Zinc chloride fume: 2 mg/m^3 Zinc oxide: 10 mg/m^3 (Respirable fraction)

OTHER HAZARDS

OTHER HAZARDS	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Ergonomic Exposure	Lifting, pushing, pulling, bending, heavy work.	**Reproduction**: • No adverse effects on male reproductive function have been noted[3] **Sexual function**: • No adverse effects on male sexual function have been noted[3]	None
	Prolonged standing.	**Reproduction**: • No adverse effects on male reproductive function have been noted **Sexual function**: • No adverse effects on male sexual function have been noted	None
	Prolonged sitting.	**Reproduction**: • Insufficient evidence to suggest that sitting causes infertility in men, more than standing[10], [26], [103] • However, when prolonged sitting causes a higher scrotal temperature, for example using a laptop computer on your lap,[15] it may lead to decreased sperm count[55] • Sitting duration is associated with increased scrotal temperature and both are associated with lower sperm counts[20], [9] • Truck and taxi drivers that sit for prolonged periods have negative effects on their fertility[20], [104] • Studies comparing tight versus loose underwear show similar results [7] • Laptop computers have also been shown to overheat the scrotum [18]	Although studies have not shown consistent connections between prolonged sitting and infertility, anything that impedes scrotal heat loss will affect testicular temperature and in turn any elevation of testicular temperature will have a harmful effect on spermatogenesis. In general the more prolonged the elevation in testicular temperature, the greater the negative consequence to the sperm.[7] Therefore, recommendations to remove factors that might impede normal cooling of the scrotum/testes are logical; particularly for men who are attempting to father a pregnancy and especially if they know they have low sperm counts or low sperm mobility take steps to minimize scrotal heating.[7] Sit with thighs apart wear clothing that encourages good air exchange.[105] Change positions, from seated to standing, to walking, etc. as often as possible at work.[55] See also action to avoid under “Extremes of Heat”.

OTHER HAZARDS	EXAMPLES IN THE MINING INDUSTRY	RISK: MALE WORKER AND FETUS (when applicable)	ACTION TO AVOID RISK
Scheduling	Working hours, shift rotation, and shift duration/night shift.	**Reproduction**: • Shift work has been shown to be related to infertility and to reduced semen motility/morphology[106], [64] • Insufficient evidence that long work schedules (e.g. 14-28 days without interruption) negatively impact fertility **Sexual function**: • Insufficient data	If fertility issues are suspected and no other causative agent is identified, alterations of work hours/schedule may be considered.
Occupational and Non-occupational Stress	Death of a spouse, divorce, job loss, loss of work, high job demands and minimal job control or workplace conflicts.	**Reproduction**: • Occupational stress and burnout related to male infertility and reduced semen motility/morphology [107], [32], [10], [64] also shown in animals[3] **Sexual function**: • Reduced testosterone levels, negatively impacts on spermatogenesis, on semen motility/morphology, may affect libido and sexual performance[108], [64], [3]	Seek psychosocial support to learn coping/stress management skills.[3] Modify job tasks to support a stress-free environment and promote work-life balance.[3]

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