

Systematic review of the association between oil and natural gas extraction processes and human reproduction

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This systematic review identified 45 original published research articles related to oil and gas extraction activities and human reproductive endpoints. Reproductive outcomes were categorized as [1] birth outcomes associated with maternal exposure, [2] semen quality, fertility, and birth outcomes associated with adult paternal exposure, [3] reproductive cancers, and [4] disruption of human sex steroid hormone receptors. The results indicate there is moderate evidence for an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer. The quality of the evidence is low and/or inadequate for stillbirth, sex ratio, and birth outcomes associated with paternal exposure, and testicular cancer, female reproductive tract cancers, and breast cancer, and the evidence is inconsistent for an increased risk of low birth weight; therefore, no conclusions can be drawn for these health effects. There is ample evidence for disruption of the estrogen, androgen, and progesterone receptors by oil and gas chemicals, which provides a mechanistic rationale for how exposure to oil and gas activities may increase the health risks we have outlined. The results from this systematic review suggest there is a negative impact on human reproduction from exposure to oil and gas activities. Many of the 45 studies reviewed identified potential human health effects. Most of these studies focused on conventional oil and gas activities. Few studies have been conducted to evaluate the impact of unconventional oil and gas operations on human health. The impact of unconventional oil and gas activities may be greater than that of conventional activity, given that unconventional activities employ many of the same approaches and use dozens of known endocrine-disrupting chemicals in hydraulic fracturing. (*Fertil Steril*® 2016;106:795–819. ©2016 by American Society for Reproductive Medicine.)

Key Words: Birth defects, cancer, oil and natural gas, human reproduction, hydraulic fracturing, endocrine disrupting chemicals, environmental pollution, fracking, hormonal activity, prenatal exposure, preterm birth, semen quality

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The world's need for energy is met substantially by natural gas and oil. In February 2016 alone, the United States produced 9 million barrels of oil and 92 billion cubic feet of natural gas per day (1, 2). As of 2014 there were 514,786 producing gas wells, and natural gas has been forecast to be the leading source of energy by 2040 (3).

Increased production of oil and gas has been facilitated by the use of unconventional oil and gas extraction, which involves directional drilling and hydraulic fracturing to access previously unreached sources of oil and gas (tight gas, coal bed methane, and shale gas). Unconventional oil extraction is projected to increase from

35% of the U.S. oil production in 2008 to 50% by the year 2019 (2). With this increased production, there is the potential for increased exposure to chemicals and products from oil and gas extraction, processing, and wastewater, which may increase the risk for adverse human health effects.

Conventional and unconventional oil and natural gas extraction activities, including drilling, hydraulic fracturing, extraction, processing, transportation and disposal of wastewater, lead to many opportunities for environmental contamination with the chemicals used in and produced during these processes. Potential routes of human exposure to these chemicals and products include

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inhalation, dermal, and oral exposure. Chemicals can be volatilized or aerosolized during extraction and by active evaporating pits, flares, surface spills, processing, and transportation (4–6). Oil and gas industry activities can contaminate surface, ground, and drinking water through the drilling process, hydraulic fracturing, failure of well casings, wastewater spills, and structural failure in abandoned wells (5–10). This has led to concerns about health risks to those exposed to the chemicals used and produced in the oil and gas industry either via residential proximity or occupational exposure (11–13).

One health effect of particular concern is the impact on human reproduction. Human reproduction is controlled by hormones in the hypothalamic, pituitary, and gonadal axis. We have shown that many chemicals used in oil and gas extraction processes can disrupt hormone receptors, the endocrine system, and development (5, 14–16). We previously reviewed the literature on a limited number of chemicals associated with unconventional oil and gas extraction and found that many are associated with adverse reproductive outcomes (17). More

recently, Elliott et al. (18) performed a systematic evaluation of chemicals used in hydraulic fracturing fluids for reproductive or developmental toxicity in the ReproTox database. Out of 1,021 chemicals identified in hydraulic fracturing fluids, 240 chemicals had toxicity information. Of this subset, 43% were suggestive of reproductive toxicity. Although individual oil and gas chemicals have been linked to reproductive toxicity, few studies have assessed human exposure to individual chemicals. The objective of this review was to systematically evaluate original published research examining potential human reproductive health effects associated with exposure to both conventional and unconventional oil and gas extraction operations.

MATERIALS AND METHODS

Literature Search

Four literature search strategies were used to comprehensively identify published literature on this topic.

TABLE 1

Terms in search 1 and search 2.

Oil and gas terms

Coal bed methane	Crude oil	Hydrofracking	Petroleum	Unconventional gas
Coal seam gas	Fracking	Natural gas	Shale	Unconventional oil
Coal bed methane	Hydraulic fracturing	Oil and gas	Tight oil	

Reproduction terms

Abortion	Epidydimis	Luteinization	Parturition	Sertoli
Acrosome	Estrogen	Luteolysis	Paternal age	Sertoli cell-only syndrome
Adnexa	Estrous	Lymphnagiogenesis	Penile	Sex
Adrenarch	Estrus	Maternal	Penile erection	Sex characteristics
Androgen	Fecundity	Maternal age	Penis	Sex determination
Andropause	Fertile	Maternal-fetal exchange	Perimenopause	Sex differentiation
Anestrus	Fertility	Menarche	Peripartum	Sexual development
Anogenital	Fertilization	Menopause	Placenta	Sexual maturation
Anovulation	Fetal development	Menstrual	Placentation	Sperm
Aspermia	Fetal movement	Menstruation	Postmenopause	Sperm capacitation
Asthenozoospermia	Fetal organ	Metestrus	Postpartum	Sperm maturation
Birth	Fetal organ maturity	Miscarriage	Pregnancy	Sperm transport
Birth rate	Fetal viability	Multiple pregnancy	Pregnancy loss	Sperm-ovum interaction
Breech	Fetal viability	Musculoskeletal development	Pregnancy maintenance	Spermatzoa
Bulbourethral glands	Fetal weight	Neurogenesis	Pregnancy outcome	Spermatoc cord
Cementogenesis	Follicular	Neurulation	Pregnancy rate	Spermatogenesis
Cervical	Follicular	Obstetric	Premenopause	Still birth
Cervix	Follicular atresia	Odontogenesis	Prenatal nutritional physiological phenomena	Subfertility
Climacteric	Gametogenesis	Oligospermia	Proestrus	Superfetation
Coitus	Gastrulation	Oogenesis	Progesterone	Superovulation
Contraception	Genitalia	Organogenesis	Prostate	Term birth
Contraception behavior	Germ cell	Orgasm	Psuedopregnancy	Testes
Corpus luteum	Gestational age	Ovarian reserve	Puberty	Testis
Dentinogenesis	Gonads	Ovary	Puberty	Trimesters
Diestrus	Gravidity	Oviparity	Reproduction	Uterus
Ectogenesis	Infertility	Oviposition	Reproductive	Vagina
Ejaculation	Insemination	Ovoviviparity	Reproductive behavior	Vas deferens
Ejaculatory ducts	Lactation	Ovulation	Reproductive physiologic processes	Vitellogenesis
Embryonic and fetal development	Lacteal elimination	Ovulation inhibition	Reproductive physiological phenomena	Viviparity
Embryonic development	Live birth	Ovum	Scrotum	Vulva
Embryonic induction	Luteal	Parity	Seminal vesicles	

Balise. Oil and gas and reproduction. Fertil Steril 2016.

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