



Potential Neurodevelopmental Effects of Oil and Gas Operations: A Literature Review

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Center for Environmental Health

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MISSION

We protect people from toxic chemicals by working with communities, consumers, workers, government, and the private sector to demand and support business practices that are safe for public health and the environment.

VISION

Our work aims to create a world in which all people live, work, learn, and play in healthy environments.

VALUES

Health and Well-being

Social and Environmental Justice

Healthy Economy

Healthy Democracy

Collaboration

Outline

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- Study Methods & Goals
- UOG Routes of Exposure
- Susceptibility & Pathways of Exposure
- Chemicals of Concern & Health Outcomes
- Future Research & Policy Recommendations



Goal of Literature Review

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We review the scientific literature providing evidence that prenatal and early life exposure to chemicals associated with UOG operations can result in adverse neurological dysfunction and neurodevelopmental harm.



Literature Review

Literature was collected from the following sources:

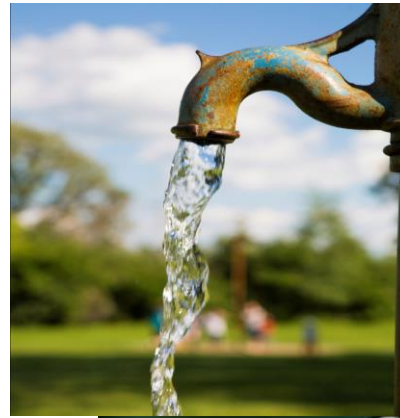
- Peer-Reviewed Bibliographic databases: *PubMed*, *Web of Science*, and *Science Direct* was undertaken.
- Searches in Physicians, Scientists and Engineers for Healthy Energy (PSE) citation database and Columbia University Library
- Searches in *Google* and *Google Scholar*
- Manual searches of peer-reviewed studies including key words (i.e. health impacts, children, women, neurodevelopment, neurological) was conducted.

Potential Route: Water

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Unconventional oil and gas operations can contaminate both surface and ground water (Warner, 2012; Fontenot et al. 2013).

Improper treatment, disposal and reuse of produced and wastewater which can eventually get into the groundwater and/or enter local water supplies and lead to agricultural pollution (Rozell et al. 2011; Vidic 2013; Shonkoff 2014).



Potential Route: Air

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- The release of VOCs from some of these sources can include BTEX and can occur during venting, flaring, production, and from leaks due to faulty casings (*Gilman et al. 2013*).
- A cluster of wells located in a small area can lead to significant accumulation of VOCs in the surrounding air (*Bar-Ilan et al. 2008*).

Potential Route: Air

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Stages of UOG lifecycle associated with air pollution include extraction and processing of natural gas and oil, transportation via compressor stations and pipelines, storage tanks, truck transportation of materials use of vehicular equipment , venting, flaring, production and leaks from faulty casings.



UOG Chemicals of Concern

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Chemicals of Concern

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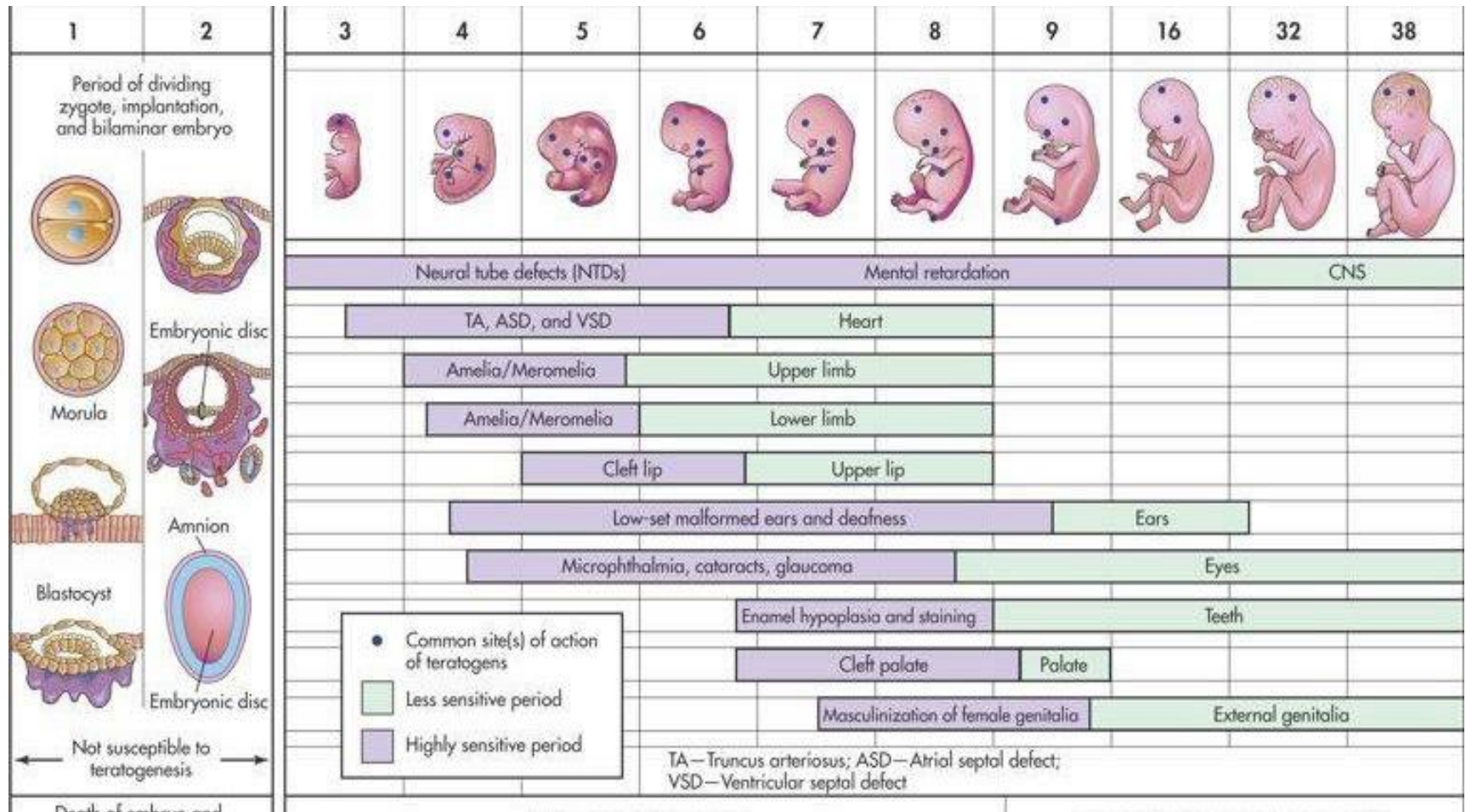
Known contributors to reduced air and water quality that pose a threat to human neurological and neurodevelopmental health include:

- Volatile organic compounds (VOCs) (including benzene, toluene, ethyl benzene, and xylene (BTEX))
- Polycyclic aromatic hydrocarbons (PAHs)
- Endocrine disrupting chemicals (EDCs)
- Heavy metals (arsenic and manganese)
- Particulate matter (PM 2.5 & PM 10)



Potential Neurological and Neurodevelopmental Health Outcomes

Windows of Vulnerability: Critical Periods of Development During Gestation



Pathway of Exposure: In-Utero

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Chemicals can pass through the placenta, and through the blood-brain barrier, thus **affecting fetuses in the womb**

(Sly and Carpenter 2012; Dybing et al. 2002; and Andersen et al. 2000)



Pathways of Exposure: Infants

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Infants can also be exposed to chemicals through their **mother's breast milk**. As a result of a mother's exposure to chemicals in the environment, an increasing amount of chemicals is found in breast milk



(Landrigan et al. 2002; Sly and Carpenter 2012)

Susceptibility of Children to Chemicals

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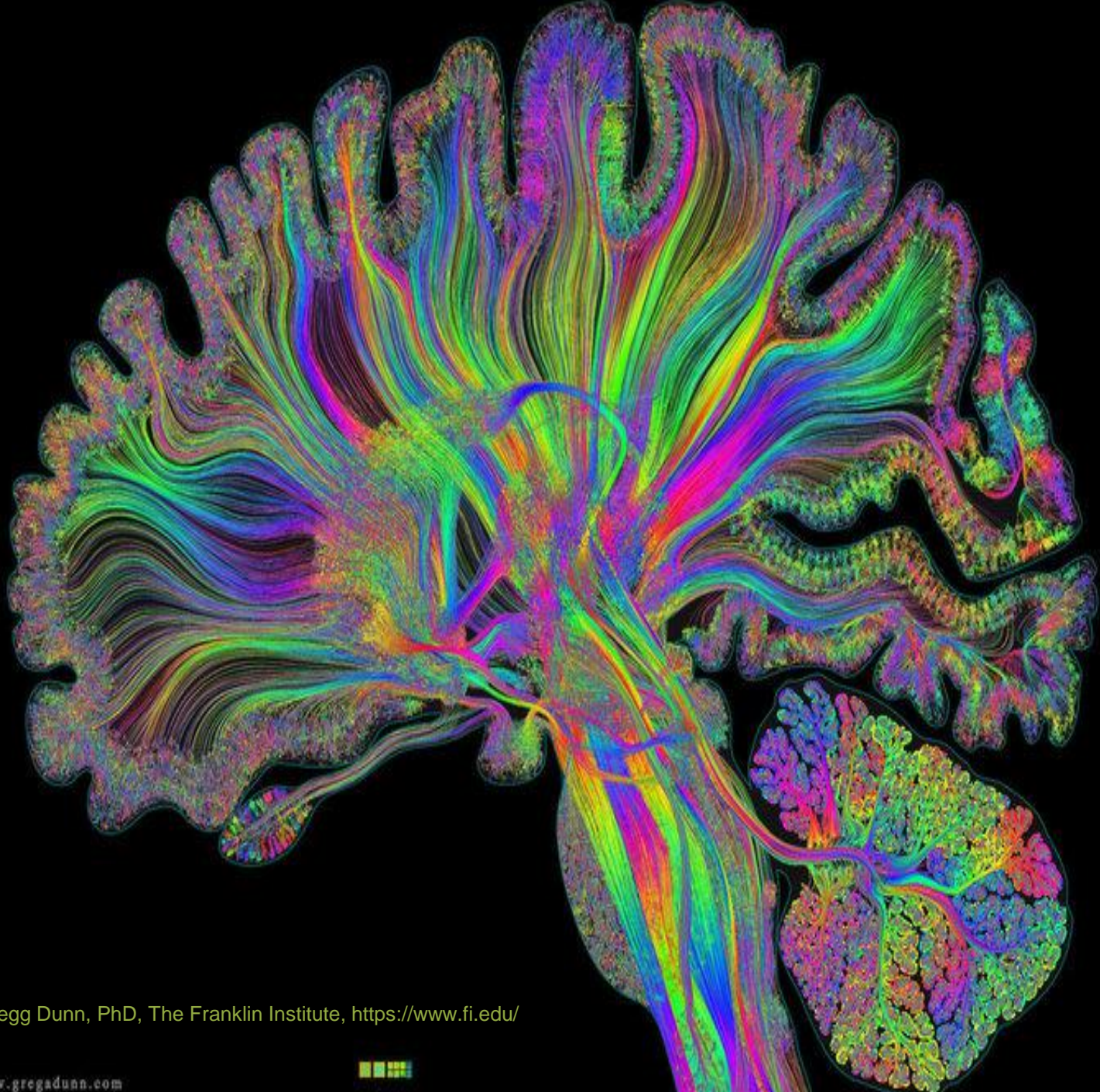
- Increased exposures and greater absorption due to rapid metabolism
- Reduced ability to detoxify compounds compared to adults
- They eat more, drink more, and breathe more per unit of body weight compared to adults
- They exhibit frequent hand to mouth behavior and play close to the ground, which exposes them to more chemicals in dust and soil

Prepubescence and Adolescence: Other Critical Windows of Vulnerability

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- Ovaries and testes are developing
- Primordial stem cells are at risk to chemical contaminants





Gregg Dunn, PhD, The Franklin Institute, <https://www.fi.edu/>



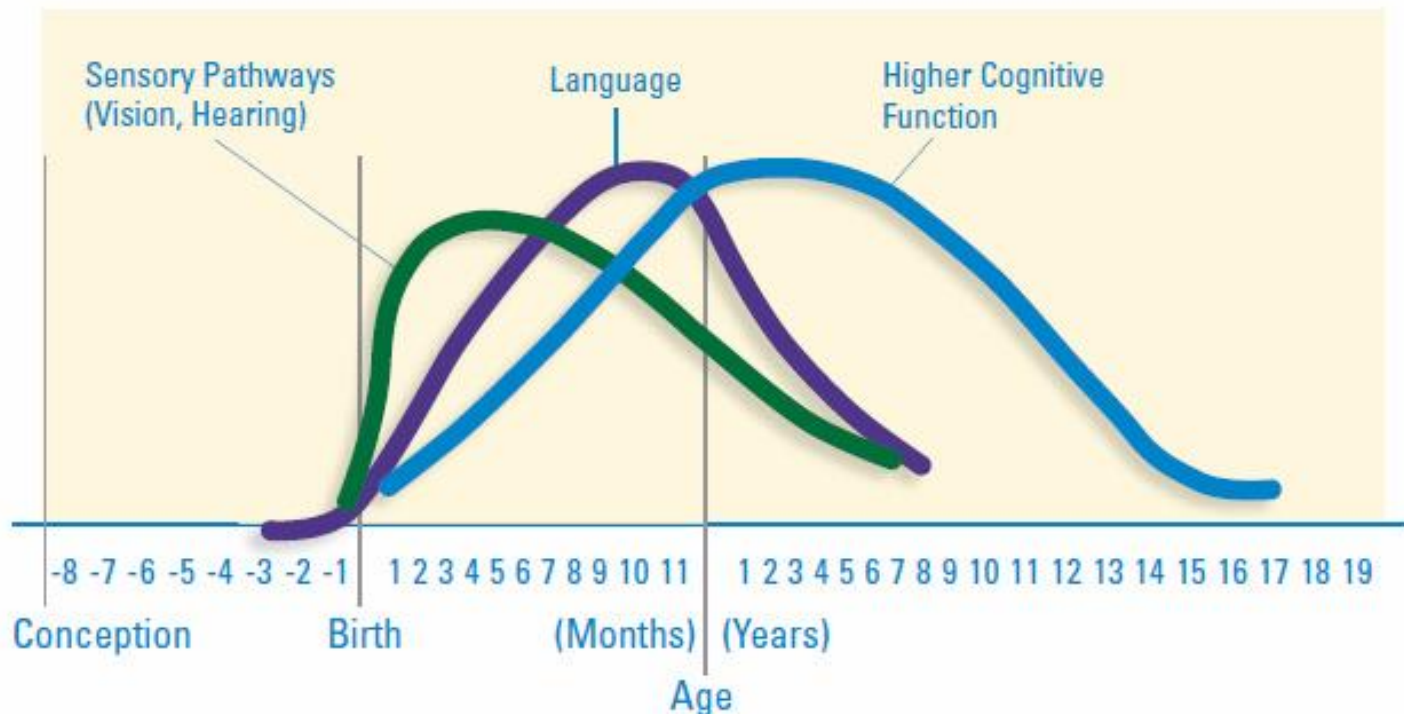
Brain Development (Only the Start....)

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“Critical Periods” Extend into Adulthood

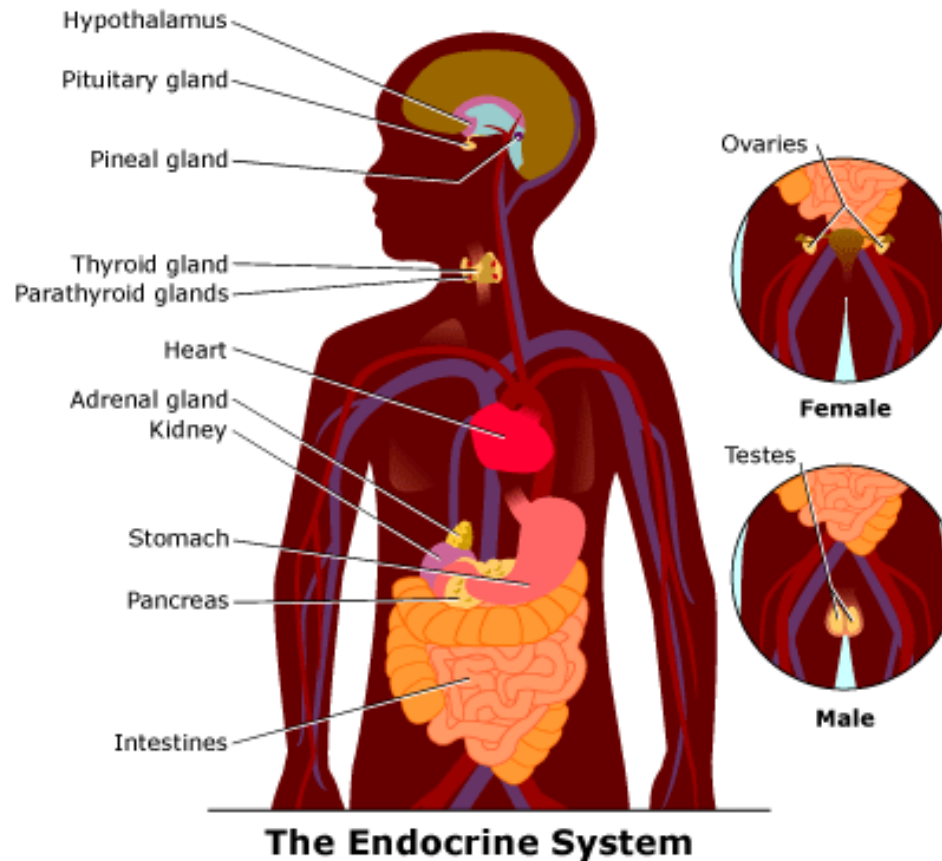
Human Brain Development
Synapse Formation Dependent on Early Experiences



Source: Nelson (2000)
National Center for Children in Poverty,
Improving the Odds for Young Children, 2008

The Endocrine system

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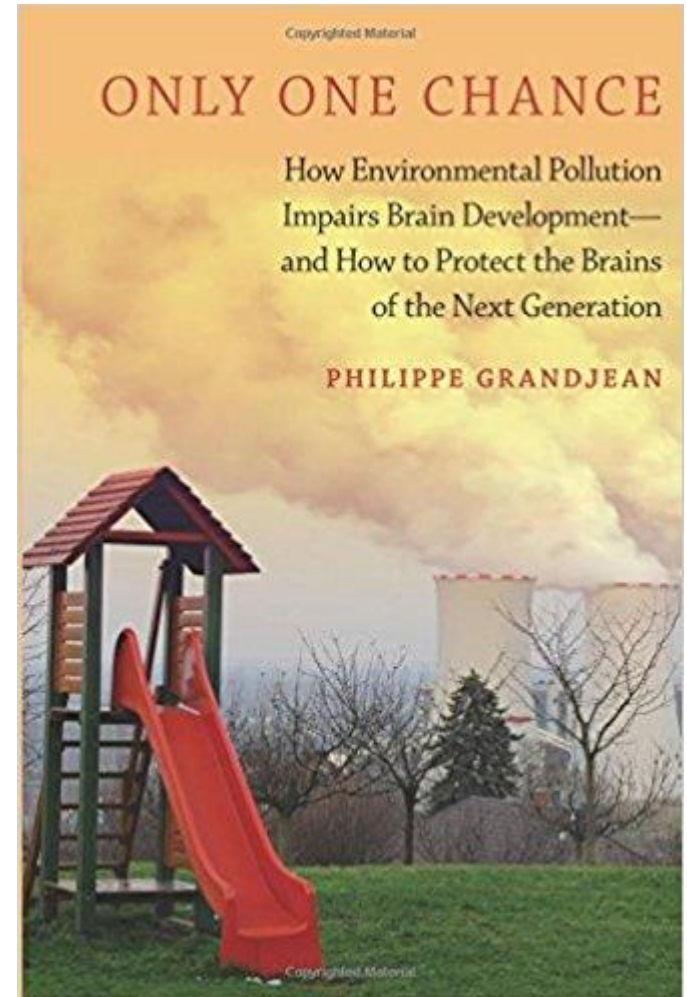


Neural Outcomes of EDC Exposure In Animal Models and Humans

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Reduction or loss of brain sex differences
Impaired spatial and working memory
Anxiety/hyperactivity
Altered social behaviors
Altered metabolic function and feeding behaviors
Impaired reproductive behavior
Premature puberty and impaired fertility (HPG axis alterations)
Disrupted myelination
Neuroinflammation

Diamanti-Kandarakis et al. (2009); Patisaul et al. (2009); Gore et al. (2010); Frye et al. (2012); Vandenberg (2014); Gore et al. (2015); Rebuli et al. (2016)



Neuropsychology & Behavior

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Significant association between high prenatal PAH exposure and ADHD behavior problems, suggesting that prenatal PAH exposure may play a role in childhood ADHD behavior problems (*Perera et al. 2014; Peterson et al. 2015*).

Conduct problems, hyperactivity, and aggressive behavior in children (*Ericson et al. 2007; Frye et al. 2012; Rahman et al. 2017*).

Symptoms of anxiety, depression and problems with self-regulation in newborns (*Perera et al. 2012; Margolis et al. 2016; Parajuli et al. 2013; Power et al. 2015*).



Neurocognitive Effects

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- **Deficits in with concentration, memory and executive functions; as well large deficits in cognition** (*Calderon-Garciduenas et al. 2008; Perera et al. 2012; Tolins et al. 2014; Gore et al. 2015*).
- **Children with high prenatal exposure showed impaired neurodevelopmental health. Reduced full-scale and verbal IQ scores at 5 YOA , and at 7 YOA** (*Perera et al. 2009; 2012*).
- **Slower processing speed index on the Weschler Scale of Intelligence and decreased performance on working memory, verbal, object assembly and picture completion tests** (*Perera 2009; Rodriguez-Barranco et al. 2013*).



Neurodevelopmental Effects

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- **Increased rates of neural tube defects from maternal exposure during pregnancy** (*Ren et al. 2001; Lupo et al. 2011; Mazumdar et al. 2015*).
- **Perinatal exposure to EDCs may cause permanent changes in the brain and behavior** (*Diamanti-Kandarakiset al. 2009; Vandenberg et al. 2012; 2014*).
- **Delayed development of speech, auditory processing, balance, neuromuscular and motor function** (*Walker 2000; Calderon-Garciduenas et al. 2011; Zhang et al. 2014*)



SGA, Reduced BW, Length and Head Circumference

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Exposures during pregnancy have been associated with:

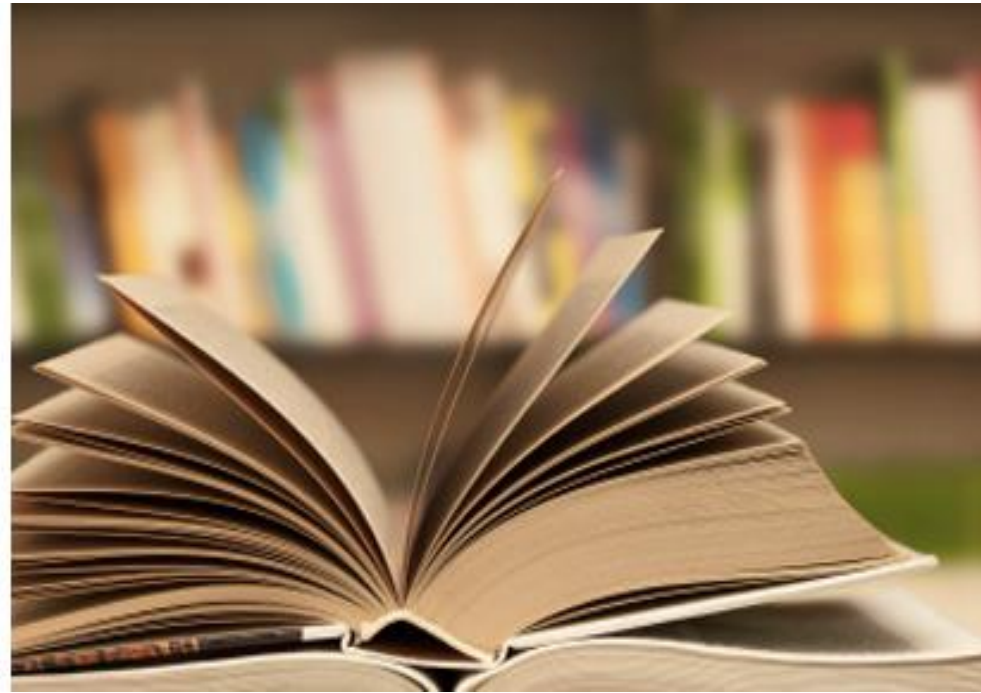
- Higher risks of pre-term births and decreased fetal growth
- Reduction in length, weight and head circumference
- **Reduction of weight & head circumference have important implications for future learning ability.** Correlates with lower IQ poorer, cognitive functioning and school performance (*Vassilev et al. 2001; Choi et al. 2008*).



Emerging Literature

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Studies have now begun to assess a more direct **link between UOG and adverse developmental and reproductive outcomes.**

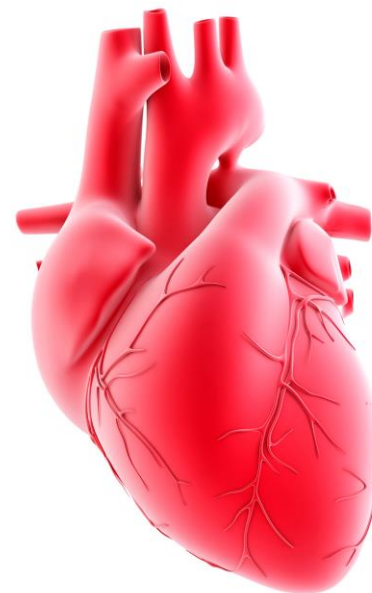


Risk of Birth Defects and Density of Gas Development

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Neural Tube Defects:
Highest tertile of exposure
OR = 2.0, 95% CI: 1.0, 3.9



Congenital Heart Disease:
Highest Tertile of Exposure
OR = 1.3 for the highest tertile
(95% CI: 1.2, 1.5)

Health Risks Identified

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At least 5 pollutant categories are associated with increased neurological and neurodevelopmental problems in developing children.

Exposure to UOG chemical pollution may have the potential to cause neurodevelopmental and neurological health effects including:

- **Neural tube defects**
- **Lower cognitive functioning/performance and difficulty learning**
- **Memory, attention and intelligence (lower IQ)**
- **Neuropsychological and behavioral effects (i.e. impaired self regulation, hyperactivity, aggression, anxiety)**
- **Motor function deficits and neuromuscular effects**



Key Take Aways

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We have enough information to know:

- There has been and continues to be a dramatic expansion of UOG operations.
- UOG development results in elevated toxic air and water contamination **near human populations**
- Large numbers of **chemicals** and lack of information
- UOG chemicals have been **directly linked with adverse neurodevelopmental and neurological health outcomes in laboratory studies.**
- UOG chemicals have been **associated with adverse human neurodevelopmental and neurological health outcomes in epidemiological studies.**



Policy Recommendations

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- Adopting the **Precautionary Approach**
- Develop science-based **surface setbacks to limit exposures**
- Where oil and gas are already happening, state agencies must put in place **more robust monitoring protocols and practices**
- **Assess the health burden, economic and social effects** of adverse neurodevelopmental health



Policy Recommendations

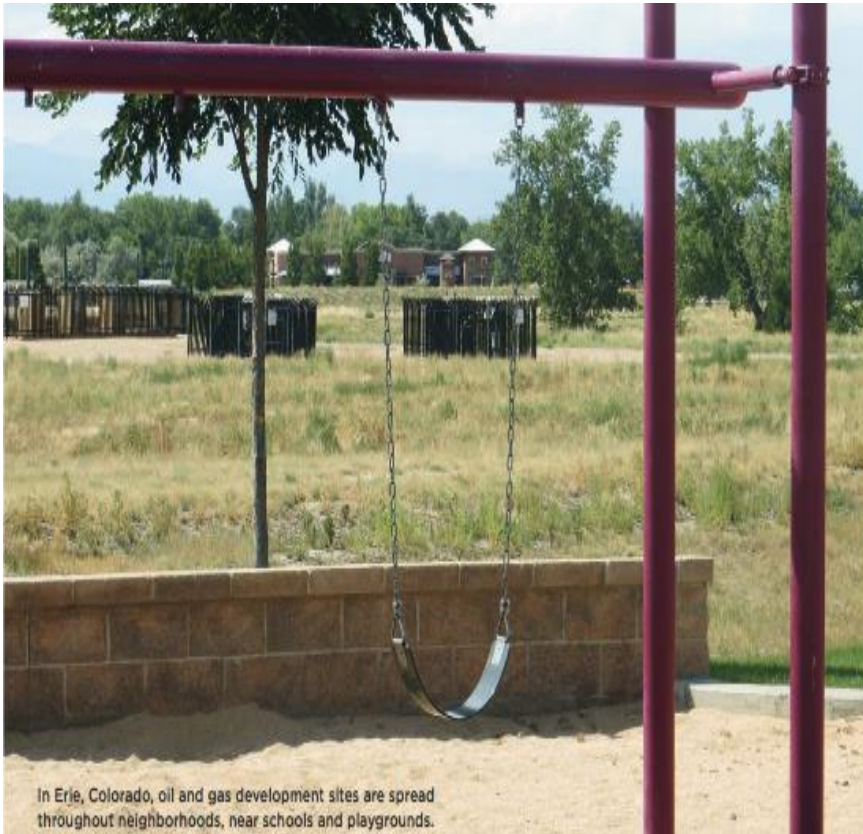
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- **Improve specificity of inventories** to allow better understanding of oil and gas air and water pollutant emissions and sources
- **Strengthen disclosure and transparency about chemicals** used in UOG because this has **clinical implications**
- Utilities, businesses and the government must invest in **sustainable energy efficiency measures clean energy solutions** to meet our nation's energy needs

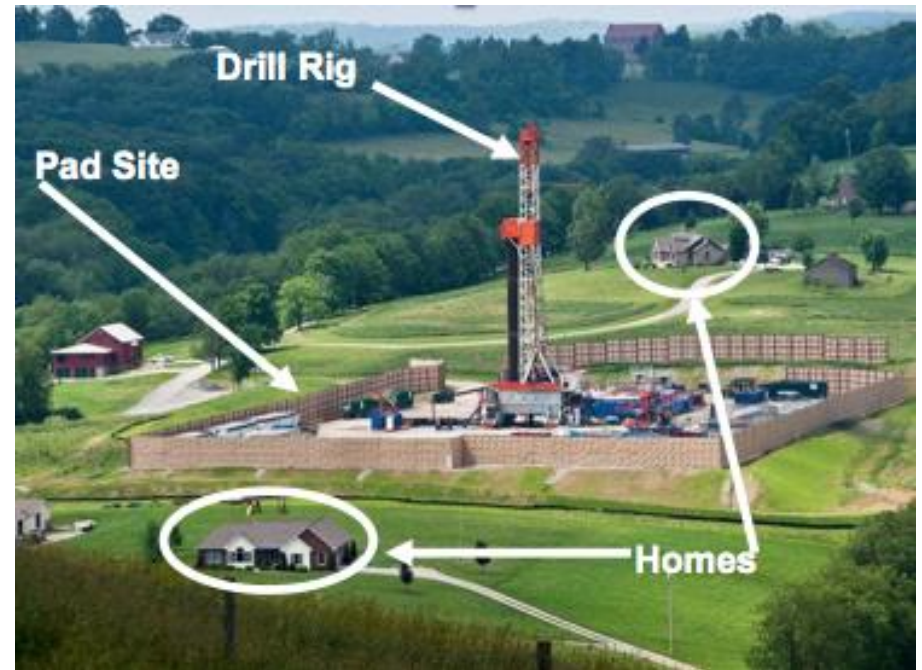


Increased Setbacks from Sensitive Receptors

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In Erie, Colorado, oil and gas development sites are spread throughout neighborhoods, near schools and playgrounds.



Source: National Geographic, <http://news.nationalgeographic.com/news/2010/10/101022-energy-marcellus-shale-gas-overview/>

Source: Warning Signs Report, Coming Clean, <http://comingcleaninc.org/assets/media/images/Reports/Warning%20Signs%20Report.pdf>



Research Recommendations

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Taken together there is an urgent need for:

- **Biomonitoring of human, domestic and wild animals for these chemicals**
- **Systematic and comprehensive epidemiological studies** to examine the potential for human harm.
- Better **population exposure assessment** is needed to document these relationships. The most accurate way to obtain information about human exposures from environmental pollution is through well-designed biomonitoring studies.



Research Recommendations

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- **Remove research barriers and improve transparency**
- **Implement scientifically based maximum contaminant levels (MCLs)**
- **Better characterization of the “windows of susceptibility”** of various human organ systems to environmental toxicants
- **Understanding** of the effect of breastfeeding on newborn exposures
- **Research on how children’s** changing behavior during development impacts opportunities for exposure



Conclusions

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There are still many “unknowns” about long-term health effects caused by recently introduced UOG toxins. **scientific literature examining the direct impact of UOG development on children is just starting to emerge.**

But much is already known about the long-term health hazards of many historical environmental toxins, linked to developmental and neurological adverse health outcomes among many generations of the American population and many subpopulations.

After decades of experience with endocrine disrupting chemicals (EDCs) and known neurodevelopmental & neurological toxins, **it is reasonable to predict what diseases may result from further environmental insults such as from UOG-related activity.**



A young boy with short hair is peeking over a field of tall green grass. He is wearing an orange and black striped shirt. The background is a soft-focus green field.

QUESTIONS?

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