Drinking Water Contaminants: Maternal and Fetal Health Risks

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ABSTRACT

Contamination of drinking water and associated health risks is becoming a serious concern worldwide. It is being increasingly recognized that the impact of water contaminants on pregnant women can be dangerous as it exposes both the mother and fetus at risk. The presence of microorganisms including bacteria, virus, and parasites, chemicals, and radioactive substances in drinking water can cause serious complications in pregnant women such as preterm delivery, miscarriage, and still birth. Fetal complications include small for gestational age, intrauterine growth retardation, congenital anomalies like oral clefts, neural tube defects, and in severe cases, fetal death. To address this issue, there is a need to collect information and a database to relate contaminated water consumption to high risk pregnancy. This could be a challenging task since in the presence of several contaminants it becomes difficult to identify which contaminant is associated with a particular adverse pregnancy outcome. Nevertheless, investigations must be carried out to gather information about the exposure toward a particular contaminant during pregnancy. Furthermore, sources of drinking water should be regularly examined to assess the presence of microbes and toxic levels of pollutants. There is also a need to conduct awareness programs among women on a regular basis, emphasizing on the health risks associated with drinking contaminated water during pregnancy.

Keywords: drinking water contaminants, pregnancy, miscarriage, intrauterine growth retardation, still birth, birth defects.

1. INTRODUCTION

Contamination of drinking water by microbial pathogens, chemicals, and radiation is a major issue affecting health of a large group of population. The problem is of key concern if it affects a woman during pregnancy, because it places the well-being of both mother and unborn child under jeopardy. A group of scientists from the Harvard School of Public Health and Center for Disease Control have reported that out of the 87 chemicals measured in the mother–child pairs, nearly all were found to have crossed the placental barrier and were present in the fetus (Needham et al., 2011). Some of the chemical contaminants being potential teratogens, serious congenital abnormalities may occur in the fetus, affecting its well-being in later life. In order to take adequate preventive measures and also for crisis management in pregnant women exposed to water-borne diseases, it is important to identify the major drinking water contaminants and understand their adverse effects on the mother and fetus.

2. EFFECT OF DRINKING WATER CONTAMINANTS ON MATERNAL AND FETAL HEALTH

2.1 Bacterial diseases

Escherichia coli (*E. coli*) is usually a commensal bacterium that lives in the gut. Virulent strains of *E. coli* can contaminate surface and ground water sources (Chen et al., 2011; Coleman et al., 2013; Ozgumus, Celik-Sevim, Alpay-Karaoglu, Sandalli, & Sevim, 2007). Pregnant women with *E. coli* infection can be easily dehydrated. Pyelonephritis is a serious condition which can be life threatening. In rare cases, *E. coli* infection can lead to severe bleeding and cause miscarriage or preterm delivery (Ovalle & Levancini, 2001). Neonatal meningitis is a serious disease with high mortality and morbidity caused by *E. coli* infection (Vale, Morais, Resende, & Taborda, 2013).

The bacterium, *Listeria monocytogenes*, has been isolated from the river Ganges in Varanasi, India (Soni, Singh, Singh, & Dubey, 2013). During pregnancy, healthy women are more susceptible toward listeriosis (Janakiraman, 2008). This can lead to preterm delivery, miscarriage, chorioamnionitis, and maternal and neonatal sepsis (Mylonakis, Paliou, Hohmann, Calderwood, & Wing, 2002). Fetal and neonatal infections have overall mortality rate of 21%, which is comparatively larger than maternal mortality rate (Schwarze, Bauermeister, Ortel, & Wichmann, 1989). In the United States, ~19% of all death in pregnancy during the second or the third trimester is attributed toward this disease (Scallan et al., 2011). The treatability of the condition implies the importance of early detection of the disease.

Shigella, an organism frequently found in human waste polluted water follows oral transmission pathway. Shigellosis, also known as bacillary dysentery, may lead to premature rupture of membranes during pregnancy (Rebarber, Star Hampton, Lewis, & Bender, 2002).

Salmonella may be found in water bodies polluted with the fecal materials of infected people or animals. Salmonellosis, an infection with *Salmonella*, can cause septicemia in pregnancy and is highly lethal to the fetus or newborn, compared to mother (Schloesser, Schaefer, & Groll, 2004).

2.2 Viral infections

Hepatitis E virus (HEV) is a virus that spreads via fecal contamination of water supplies. HEV genotype 1 is associated with disease outbreak in children and pregnant women. It is a mild-to-moderate disease in severity in pregnancy. The rate of mortality may climb up to 20% (Purcell, 1994). Every year there are 20 million hepatitis E infection and 5,700 hepatitis E-related deaths worldwide (Aggarwal, 2010). The high mortality rate in pregnancy is thought to be secondary to the associated hormonal (estrogen and progesterone) changes during pregnancy and consequent immunological changes (Navaneethan, Al Mohajer, & Shata, 2008). It may lead to fulminant hepatic failure in many patients and the mortality of disease can be controlled using an effective vaccine (Labrique et al., 2012).

Severe acute respiratory syndrome (SARS) is a respiratory viral disease of zoonotic origin (Bartram & Carr, 2004). SARS infection during pregnancy is associated with incidences of spontaneous miscarriage, preterm delivery, and intrauterine growth retardation (IUGR). In a study conducted on pregnant women with SARS ~6 months in Hong Kong, three deaths occurred out of 12 patients and four women had first trimester spontaneous miscarriage (Wong et al., 2004).

2.3 Parasitic diseases

Ascaris lumbricoides, the giant roundworm present in humans, is another most common water-borne pathogen affecting pregnancy. This infection is attributed to agriculture and unhygienic practices (Pham-Duc et al., 2013) and is reported to cause biliary ascariasis in pregnant women (Shah, Robanni, Khan, Zargar, & Javid, 2005). Physiological and anatomical changes occurring in pregnancy may attenuate infection due to biliary ascariasis (Khuroo et al., 1992).

Infection with *Giardia* can occur and be passed on via the consumption of *Giardia* cysts in contaminated water. Giardiasis can cause diarrhea, fluid, and electrolyte imbalance, malabsorbtion thereby leading to miscarriage and maternal complications (Lengerich, Addiss, & Juranek, 1994).

Toxoplasmosis is a parasitic disease caused by the protozoan *Toxoplasma gondii*. Cats shed millions of oocysts in their feces which can contaminate drinking water. If the transmission occurs near to conception the risk of infection is more to fetus and may lead to abortion (Rorman, Zamir, Rilkis, & Ben-David, 2006). The infection can be transmitted from mother to child via placenta, and it affects mainly the eyes and the nervous system of the fetus. The infection can progress to behavioral abnormalities, hearing loss, visual impairment, and mental retardation in some cases (Stray-Pedersen, 1993). It may also lead to cardiac abnormalities in newborn (Paquet & Yudin, 2013).

Malaria is a mosquito-borne infectious disease caused by the parasitic protozoan *Plasmodium*. It is endemic in ~90 countries and is responsible for 1–3 million deaths per year. *Anopheles mosquito,* the major vector of malaria, prefers clean water as its breeding place (Gunathilaka et al., 2013). It is, therefore, very important that water stored for drinking purposes should not be left uncovered. Malaria is a threat to pregnant women. Pregnant women have lower acquired immunity, and malarial infection is more likely to evolve toward clinical disease. Intrauterine transmission of malaria parasite from mother to fetus frequently occurs depending upon efficiency of placenta in blocking the parasite. Malaria increases risk of low birth weight and intrauterine growth retardation and is a cause of infant and maternal mortality (Steketee et al., 1996; Sullivan et al., 1999; Verhoeff et al., 2001).

3. CHEMICAL TOXICANTS

Increase in chemical contamination of drinking water as a result of growing industrialization is a matter of major concern. The adverse effect of various contaminants present in drinking water on pregnancy has generated considerable research interest. Walker, Rattigan, and Canterino (2011) have studied the effect of copper toxicity in pregnant women. Excessive copper levels are linked with IUGR, preeclampsia, and neurological diseases. The studies also suggest that their accumulation in tissues can contribute to cardiac dysfunction, liver cirrhosis, pancreatic dysfunction, and neurological abnormalities (Roberts & Schilsky, 2008).

Exposure to chromium can also induce complications during pregnancy and child birth (Wilbur, Ingerman, Citra, Osier, & Wohlers, 2000). Developmental defects including postimplantation losses, resorption, reduced fetal weight, and malformations are associated with high chromium levels in drinking water.

Contamination of water with Arsenic is another regional and global issue. Among other countries, India and Bangladesh are the top two countries with a higher percentage of negative impact due to

Arsenic. In Bangladesh, a key pathway of exposure is the consumption of Arsenic-contaminated water. The first report of undesirable health issues related to pregnancy in Bangladesh goes back to 2001 (Milton et al., 2003). Other research involved two-hundred-two mothers relating "pregnancy outcomes" to "infant mortality" in the state of "West Bengal" India (Von Ehrenstein et al., 2006; Mazundar, 2008). Increased level of arsenic (>= 50 mg/L) during pregnancy was found to be linked with higher risk of still birth and abortion (Milton et al., 2005). Cadmium, another trace metal, is considered to be more teratogenic after implantation. It is suggested that cadmium and arsenic influence fetal development in a sex-dependent manner (Kippler et al., 2012).

The lead in a mother's blood can cross the placenta and show up in the umbilical cord. Such lead contamination in a mother's blood is associated with multiple diseases, including IUGR, birth defects, preterm delivery, fetal neurotoxicity, and skeletal abnormalities (Weizsaecker, 2003). A lady who is not pregnant at the time of exposure can easily pass lead onto the fetus, because 90% of the lead stored in the bone is released into the blood stream after several years (Gilbert-Barness, 2010). Transfer of lead from a mother's bone could occur during pregnancy, and it further increases the probability of lead toxicity in the fetus (Weizsaecker, 2003; Riess & Halm, 2007). Various studies have indicated linkage of the mother's exposure to lead via contaminated drinking water with the abnormalities of the child (Weizsaecker, 2003). Another heavy metal, mercury, can cross placenta and affect the development of brain (Gundacker & Hengstschlager, 2012).

Nitrate toxicity is associated with in vivo conversion of nitrate to nitrite after ingestion. Nitrogen fertilizers are generally used to enrich soils since nitrates are a critical source of nitrogen for plants. Rain, irrigation, and other surface water systems tend to transport the nitrates through the soil to the ground water. Another contributory factor toward nitrate contamination of drinking water is the human and animal wastes. Maternal intake of nitrates ≥5 mg/d is reported to be associated with increased tendency of newborn to have neural tube defects, oral clefts, congenital cardiac defects, and limb deficiencies (Brender et al., 2013; Cedergren, Selbing, Lofman, & Kallen, 2002; Croen, Todoroff, & Shaw, 2001).

The presence of pesticide residues in drinking water poses to be a major threat to maternal and fetal well-being. Increasing amount of total serum dichlorodiphenyltrichloroethane (DDT) concentration is reported to increase the chance of early pregnancy losses (Venners et al., 2005). Polycyclic aromatic hydrocarbons (PAHs) are widespread pollutants commonly found in air, food, and drinking water. Compromised fetal development following transplacental exposure to PAH is evidenced (Bove, Shim, & Zeitz, 2002). Trihalomethanes (THMs) are formed as a byproduct when water is cleaned using chlorine. Various studies prove that intake of THMs during pregnancy can lead to cardiac defects, small for gestational age, low birth weight, preterm delivery, spontaneous abortion, oral clefts, and neural tube defects.

It is well established that consumption of water with a high level of radioactive toxicants by pregnant women exposes them at an increased risk of spontaneous abortion and giving birth to babies with congenital defects. Daily intake of uranium in food and water varies from ~1–5 mg/d in uncontaminated regions to 13–18 per day or more in uranium-mining areas (Taylor & Taylor, 1997). Reduced growth of the offspring and fetal toxicity including teratogenicity has been observed following uranium exposure in animal experiments (Domingo, 2001). Radon is the decay product of radium. A study conducted by Schieve et al. (1997) has shown that radium exposure during pregnancy can cause still births.

4. CHALLENGES AHEAD

An excellent review by Bove et al. (2002) mentions that a majority of the states in the U.S. keep records of supplied water samples as per the applicable drinking water law—both federal and state. Moreover, information related to birth and associated parent-related risk attributes are kept at the state level. These databases are used to study links between drinking water contamination and adverse birth outcomes. Unfortunately, such a database is yet to be developed and made available in India.

5. CONCLUSION

Studies indicate linkage between contaminated water consumption and high risk pregnancy. Though challenging, in the presence of multiple contaminants, there is a need to identify which contaminant in the drinking water system is associated with a particular adverse pregnancy outcome. Future studies should be directed toward individual exposure assessments in both the rural and urban areas. Surveys must be carried out to gather information about the exposure toward a particular contaminant particularly during pregnancy. A database should be maintained for children born with congenital defects, and a proper investigation should be done on the water supply system in that community. Sources of water in the community should

be routinely examined to assess the level of heavy metals and the presence of microorganisms. Finally, awareness programs to prevent the spread of water-borne diseases may be conducted among women in rural areas, wherein illiteracy and lack of knowledge are a major concern.

REFERENCES

Aggarwal, R. (2010). *The global prevalence of hepatitis E virus infection and susceptibility: A systematic review*. Geneva, Switzerland: World Health Organization. Retrieved from http:// whqlibdoc.who.int/hq2010/WHO_ IVB_10.14_eng.pdf.

Bartram, J., & Carr, R. (2004). *An introduction to emerging waterborne zoonoses and eneral control principles. Waterborne zoonoses: Identification causes and control (Section 2)*. Retrieved from http://www.who.int/water_sanitation_health/ diseases/zoonosessect2.pdf

Bove, F., Shim, Y., & Zeitz, P. (2002). Drinking water contaminants and adverse pregnancy outcomes: A review. *Environmental Health Perspectives, 1*, 61–74. Retrieved from http://www.ncbi.nlm.nih. gov/pubmed/11834464

Brender, J. D., Weyer, P. J., Romitti, P. A., Mohanty, B. P., Shinde, M. U., Vuong, A. M., & Canfield, M. A. (2013). Prenatal nitrate intake from drinking water and selected birth defects in offspring of participants in the national birth defects prevention study. *Environmental Health Perspectives, 14*, 14. doi:10.1289/ehp.1206249

Cedergren, M. I., Selbing, A. J., Lofman, O., & Kallen, B. A. (2002). Chlorination byproducts and nitrate in drinking water and risk for congenital cardiac defects. *Environmental Research, 89*(2), 124–130. doi:10.1006/enrs.2001.4362

Chen, B., Zheng, W., Yu, Y., Huang, W., Zheng, S., Zhang, Y., … Topp, E. (2011). Class 1 integrons, selected virulence genes, and antibiotic resistance in *Escherichia coli* isolates from the Minjiang River, Fujian Province, China. *Applied and Environmental Microbiology, 77*(1), 148–155. doi:10.1128/ AEM.01676-10

Coleman, B. L., Louie, M., Salvadori, M. I., McEwen, S. A., Neumann, N., Sibley, K., & McGeer, A. J. (2013). Contamination of Canadian private drinking water sources with antimicrobial resistant *Escherichia coli*. *Water Research, 47*(9), 3026–3036. doi:10.1016/j. watres.2013.03.008

Croen, L. A., Todoroff, K., & Shaw, G. M. (2001). Maternal exposure to nitrate from drinking water and diet and risk for neural tube defects. *American Journal of Epidemiology, 153*(4), 325–331. doi:10.1093/aje/153.4.325

Domingo, J. L. (2001). Reproductive and developmental toxicity of natural and depleted uranium: A review. *Reproductive Toxicology, 15*(6), 603–609. doi:10.1016/S0890- 6238(01)00181-2

Gilbert-Barness, E. (2010). Teratogenic causes of malformations. *Annals of Clinical and Laboratory Science, 40*(2), 99–114. Retrieved from http:// www.annclinlabsci.org/content/40/2/99.long

Gunathilaka, N., Fernando, T., Hapugoda, M., Wickremasinghe, R., Wijeyerathne, P., & Abeyewickreme, W. (2013). *Anopheles culicifacies* breeding in polluted water bodies in Trincomalee District of Sri Lanka. *Malaria Journal, 12*(1), 285. doi:10.1186/1475-2875-12-285

Gundacker, C., & Hengstschlager, M. (2012). The role of the placenta in fetal exposure to heavy metals. *Wiener Medizinische Wochenschrift, 162*(9–10), 201–206. doi:10.1007/s10354-012-0074-3

Janakiraman, V. (2008). Listeriosis in pregnancy: Diagnosis, treatment, and prevention. *Reviews in Obstetrics and Gynecology, 1*(4), 179–185. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/ articles/PMC2621056/

Khuroo, M. S., Zargar, S. A., Yattoo, G. N., Dar, M. Y., Javid, G., Khan, B. A., & Mahajan, R. (1992). Sonographic findings in gallbladder ascariasis. *Journal of Clinical Ultrasound: JCU, 20*(9), 587–591. Retrieved from http://www.ncbi. nlm.nih.gov/pubmed/1331185

Kippler, M., Wagatsuma, Y., Rahman, A., Nermell, B., Persson, L. A., Raqib, R., & Vahter, M. (2012). Environmental exposure to arsenic and cadmium during pregnancy and fetal size: A longitudinal study in rural Bangladesh. *Reproductive Toxicology, 34*(4), 504–511. doi:10.1016/j. reprotox.2012.08.002

Labrique, A. B., Sikder, S. S., Krain, L. J., West, K. P., Jr., Christian, P., Rashid, M., & Nelson, K. E. (2012). Hepatitis E, a vaccine-preventable cause of maternal deaths. *Emerging Infectious Diseases, 18*(9), 1401–1404. doi:10.3201/ eid1809.120241

Lengerich, E. J., Addiss, D. G., & Juranek, D. D. (1994). Severe giardiasis in the United States. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America, 18*(5), 760–763. doi:10.1093/ clinids/18.5.760

Mazumdar, D. N. G. (2008). Chronic arsenic toxicity & human health. *Indian Journal of Medical Research, 128*(4), October, 436–447.

Milton, A. H., Smith, W., Rahman, B., Hasan, Z., Kulsum, U., Dear, K., & Ali, A. (2005). Chronic arsenic exposure and adverse pregnancy

outcomes in Bangladesh. *Epidemiology, 16*(1), 82–86. doi:10.1097/01.ede.0000147105.94041.e6

Mylonakis, E., Paliou, M., Hohmann, E. L., Calderwood, S. B., & Wing, E. J. (2002). Listeriosis during pregnancy: A case series and review of 222 cases. *Medicine (Baltimore), 81*(4), 260–269. doi:10.1097/00005792-200207000-00002

Navaneethan, U., Al Mohajer, M., & Shata, M. T. (2008). Hepatitis E and pregnancy: Understanding the pathogenesis. *Liver International: Official Journal of the International Association for the Study of the Liver, 28*(9), 1190–1199. doi:10.1111/j.1478-3231.2008.01840.x

Needham, L. L., Grandjean, P., Heinzow, B., Jørgensen, P. J., Nielsen, F., Patterson, D. G. Jr., Sjödin, A., Turner, W. E., & Weihe, P. (2011). Partition of environmental chemicals between maternal and fetal blood and tissues. *Environmental Science & Technology, 45*(3):1121–1126. doi: 10.1021/es1019614

Ovalle, A., & Levancini, M. (2001). Urinary tract infections in pregnancy. *Current Opinion in Urology, 11*(1), 55–59. doi:10.1097/00042307-200101000-00008

Ozgumus, O. B., Celik-Sevim, E., Alpay-Karaoglu, S., Sandalli, C., & Sevim, A. (2007). Molecular characterization of antibiotic resistant *Escherichia coli* strains isolated from tap and spring waters in a coastal region in Turkey. *Journal of Microbiology, 45*(5), 379–387. Retrieved from http://www.msk.or.kr/jsp/view_old_journalD.jsp?paperSeq=2600

Paquet, C., & Yudin, M. H. (2013). Toxoplasmosis in pregnancy: Prevention, screening, and treatment. *Journal d'Obstétrique et Gynécologie Du Canada: JOGC, 35*(1), 78–79. Retrieved from http://sogc.org/guidelines/toxoplasmosis-in-pregnancy-prevention-screening-and-treatment

Pham-Duc, P., Nguyen-Viet, H., Hattendorf, J., Zinsstag, J., Phung-Dac, C., Zurbrügg, C., & Odermatt, P. (2013). *Ascaris lumbricoides* and *Trichuris trichiura* infections associated with wastewater and human excreta use in agriculture in Vietnam. *Parasitology International, 62*(2), 172–180. doi:10.1016/j.parint.2012.12.007

Purcell, R. H. (1994). Hepatitis viruses: Changing patterns of human disease. *Proceedings of the National Academy of Sciences of the United States of America, 91*(7), 2401–2406. doi:10.1073/pnas.91.7.2401

Rebarber, A., Star Hampton, B., Lewis, V., & Bender, S. (2002). Shigellosis complicating preterm premature rupture of membranes resulting in congenital infection and pretermdelivery. *Obstetrics and Gynecology, 100*(5Pt2), 1063–1065. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12423805

Riess, M. L., & Halm, J. K. (2007). Lead poisoning in an adult: Lead mobilization by pregnancy? *Journal of General Internal Medicine, 22*(8), 1212–1215. doi:10.1007/s11606-007-0253-x

Roberts, E. A., & Schilsky, M. L. (2008). Diagnosis and treatment of Wilson disease: An update. *Hepatology, 47*(6), 2089–2111. doi:10.1002/hep.22261

Rorman, E., Zamir, C. S., Rilkis, I., & Ben-David, H. (2006). Congenital toxoplasmosis – Prenatal aspects of *Toxoplasma gondii* infection. *Reproductive Toxicology, 21*(4), 458–472. doi:10.1016/j.reprotox.2005.10.006

Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., & Griffin, P. M. (2011). Foodborne illness acquired in the United States – Major pathogens. *Emerging Infectious Diseases, 17*(1), 7–15. doi:10.3201/eid1701.P11101

Schieve, L. A., Davis, F., Roeske, J., Handler, A., Freels, S., Stinchcomb, T., & Keane, A. (1997). Evaluation of internal alpha-particle radiation exposure and subsequent fertility among a cohort of women formerly employed in the radium dial industry. *Radiation Research, 147*(2), 236–244. doi:10.2307/3579425

Schloesser, R. L., Schaefer, V., & Groll, A. H. (2004). Fatal transplacental infection with non-typhoidal salmonella. *Scandinavian Journal of Infectious Diseases, 36*(10), 773–774. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15513410

Schwarze, R., Bauermeister, C. D., Ortel, S., & Wichmann, G. (1989). Perinatal listeriosis in Dresden 1981-1986: Clinical and microbiological findings in 18 cases. *Infection, 17*(3), 131–138. doi:10.1007/BF01644011

Shah, O. J., Robanni, I., Khan, F., Zargar, S. A., & Javid, G. (2005). Management of biliary ascariasis in pregnancy. *World Journal of Surgery, 29*(10), 1294–1298. doi:10.1007/s00268-005-0015-z

Soni, D. K., Singh, R. K., Singh, D. V., & Dubey, S. K. (2013). Characterization of *Listeria monocytogenes* isolated from Ganges water, human clinical and milk samples at Varanasi, India. *Infection, Genetics and Evolution, 14,* 83–91. doi:10.1016/j.meegid.2012.09.019

Steketee, R. W., Wirima, J. J., Hightower, A. W., Slutsker, L., Heymann, D. L., & Breman, J. G. (1996). The effect of malaria and malaria prevention in pregnancy on offspring birthweight, prematurity, and intrauterine growth retardation in rural Malawi. *The American Journal of Tropical Medicine and Hygiene, 55*(1 Suppl.), 33–41. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8702035

Stray-Pedersen, B. (1993). Toxoplasmosis in pregnancy. *Bailliere's Clinical Obstetrics and*

Gynaecology, 7(1), 107–137. doi:10.1016/S0950-3552(05)80149-X

Sullivan, A. D., Nyirenda, T., Cullinan, T., Taylor, T., Harlow, S. D., James, S. A., & Meshnick, S. R. (1999). Malaria infection during pregnancy: Intrauterine growth retardation and preterm delivery in Malawi. *The Journal of Infectious Diseases, 179*(6), 1580–1583. doi:10.1086/314752

Taylor, D. M., & Taylor, S. K. (1997). Environmental uranium and human health. *Reviews on Environmental Health, 12*(3), 147–157. doi:10.1515/REVEH.1997.12.3.147

Vale, B., Morais, S., Resende, C., & Taborda, A. (2013). Neonatal meningitis associated with osteomyelitis and epidural empyema. *BMJ Case Report, 23*(10), 2013–009149. doi:10.1136/bcr-2013-009149

Venners, S. A., Korrick, S., Xu, X., Chen, C., Guang, W., Huang, A., & Wang, X. (2005). Preconception serum DDT and pregnancy loss: A prospective study using a biomarker of pregnancy. *American Journal of Epidemiology, 162*(8), 709–716. doi:10.1093/aje/kwi275

Verhoeff, F. H., Brabin, B. J., van Buuren, S., Chimsuku, L., Kazembe, P., Wit, J. M., & Broadhead, R. L. (2001). An analysis of intra-uterine growth retardation in rural Malawi. *European Journal of Clinical Nutrition, 55*(8), 682–689. doi:10.1038/sj.ejcn.1601200

Von Ehrenstein, O. S., Guha Mazumder, D. N., Hira-Smith, M., Ghosh, N., Yuan, Y., Windham, G., … Smith, A. H. (2006). Pregnancy outcomes, infant mortality, and arsenic in drinking water in West Bengal, India. *American Journal of Epidemiology, 163*(7), 662–669. doi:10.1093/aje/ kwj089

Walker, L. R., Rattigan, M., & Canterino, J. (2011). A case of isolated elevated copper levels during pregnancy. *Journal of Pregnancy, 2011*: 385767. doi:10.1155/2011/385767

Weizsaecker, K. (2003). Lead toxicity during pregnancy. *Primary Care Update for OB/GYNs, 10*(6), Nov–Dec, 304–309.

Wilbur, S., Ingerman, L., Citra, M., Osier, M., & Wohlers, D. (2000). *Toxicological profile for chromium. Agency for toxic substances and disease registry, Atlanta, Georgia*. Retrieved from http://www.atsdr.cdc.gov/ toxprofiles/tp7.pdf

Wong, S. F., Chow, K. M., Leung, T. N., Ng, W. F., Ng, T. K., Shek, C. C., & Tan, P. Y. (2004). Pregnancy and perinatal outcomes of women with severe acute respiratory syndrome. *American Journal of Obstetrics and Gynecology, 191*(1), 292–297. doi:10.1016/j. ajog.2003.11.019

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