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Opinion Article

Operational Management Options for Water Management

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Description

The covariates examined in this study included infant sex, maternal age at birth, maternal race/ethnicity, maternal educational attainment, marital status, prenatal care status, socioeconomic status, parity, cigarette use, and maternal pre-pregnancy Body Mass Index (BMI). Maternal age was categorized as maternal race/ethnicity was defined as non-Hispanic white, non-Hispanic black, Hispanic, and other/unknown. Maternal educational attainment was categorized as less than a high school degree, high school degree, some college, and college degree or higher. Marital status was dichotomized as married or unmarried. The unmarried category includes mothers who responded single, widowed, or divorced. The Kotelchuck index was used to define the adequacy of prenatal care utilization, based on the month of entry into prenatal care and total number of prenatal care visits. Women were categorized as inadequate, intermediate, adequate, or adequate plus a category that indicates an individual has had more than the recommended amount of prenatal care. Maternal smoking was dichotomized as smoker versus non-smoker. The cigarette use data was non-specific to the window of time including pregnancy. Whether or not the mother was enrolled in the Women, Infant, and Children (WIC) supplemental nutrition program was used as a proxy for low SES. The WIC program is a federally funded nutrition and assistance program for low-income pregnant and post-partum women, infants, and children under the age of five. Maternal pre-pregnancy BMI was categorized according to the Centers for Disease Control and Prevention definitions of underweight, normal, overweight, and obese. Parity was categorized as having had previous live births.

Data analysis

This is a cross-sectional study of dichotomous birth outcomes among singleton births in Ohio cities served by AMP CWSs. Bivariate associations between atrazine concentrations, outcomes, and covariates were assessed using t-tests for continuous variables, Rao-Scott Chi-Square tests for dichotomous variables, and ANOVA test for covariates with 2 categories. Potential confounders were considered as those variables that were associated with both the exposure measures and outcome measures and were not conceptually in the causal pathway.

We developed Generalized Estimating Equation (GEE) logistic regression models, with an exchangeable working correlation structure and robust standard errors, to estimate the association between atrazine in drinking water and each birth outcome-SGA, term LBW,VLBW, PTB, and VPTB-while accounting for clustering at the city level. Models of continuous and categorical atrazine exposure were tested. Maternal age, maternal race/ethnicity, and year of birth were included in all adjusted models based on a priori knowledge. We assessed confounding throughout the model building process and in an effort to maximize parsimony; we retained only those variables that had a substantial effect on the estimate of the effect of atrazine in the models. Final adjusted models were built using the gestational atrazine exposure measure. The covariates identified as confounders in these models were applied to models of trimester-specific atrazine exposure. Third trimester models were not performed for the outcome VLBW because only two of the VLBW births in this population was delivered at full term. Linear GEE regression models of birth weight and gestation in weeks were performed controlling for those covariates identified in the logistic regression model-building procedures. Between 0.5 and 3.5% of observations were not used due to missing data on covariates, exposure, or outcome status. All analyses were performed using SAS.

We performed a sensitivity analysis to further reduce exposure misclassification by restricting the analysis to only those water systems where we had confirmation from on-site representatives that the service boundaries of the water system corresponded to the city limits in which it was located and that 95% of the population was likely to be receiving their public water from the AMP water system in question. Additionally, we restricted the data set to those with a gestational atrazine concentration 3 μg/L to evaluate the relationship between atrazine in drinking water and selected birth outcomes when exposure is below permissible levels in public drinking water.

This work was reviewed and approved by the Institutional Review Board of the University of Illinois at Chicago and the Institutional Review Board of the Ohio Department of Health.

There were 14,445 live singleton births within the 22 cities which received their public drinking water supply from AMP water systems in Ohio between 2006 and 2008, of which 51% were males. The majority of these births were born to mothers who were non-Hispanic white (86%), between 20 and 34 years old (81%), were married (54%), and porous (59%). Half of the births during this time period were born to mothers with a high school degree or less. Overall, 68%of mothers reported adequate plus, intermediate, or adequate prenatal care, but 19% had an unknown level of prenatal care. The proportion of infants born to mothers enrolled in the WIC program in our sample was higher than for the state as a whole as was the proportion of infants born to mothers who reported smoking. There was a high prevalence of pre-pregnancy obesity (25%) among the mothers in this population. Among live singleton births, 10.3% were SGA, 1.1% was very low birth weight, 9.9% were preterm, and 1.6% very preterm. Among singleton term births, 2.4% were term LBW. Between 1% and 3% of observations were dropped in fully covariate-adjusted models due to missing data on outcomes, covariates, or exposure estimates.

We found an association between atrazine concentrations in drinking water and the odds of term LBW births within communities

served by water systems enrolled in USEPA's Atrazine Monitoring Program in Ohio. This is the first study to show such an association for term LBW by linking maternal residence to a specific water system. Water systems are enrolled in the AMP as a result of repeated of the 3 μg/L MCL for atrazine, but only 4% of samples from the water systems in this study exceeded the MCL. We observed an increase in the odds of term LBW births among those with average gestational atrazine below the current MCL. While further epidemiologic research is needed, these results suggest that the current MCL for atrazine may not be protective against some adverse birth outcomes such as term LBW.