PhD Dissertation Defense

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ADVANCING ENVIRONMENTAL HUMAN HEALTH RISK ASSESSMENT THROUGH BAYESIAN NETWORK ANALYSIS

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Regulatory agencies rely on quantitative risk assessment to design policies, such as environmental quality standards, to protect public health. Although risk assessment forms the foundation of important policy decisions, recent reviews have indicated the need for technical and practical improvements to risk assessment. This dissertation advances the application of Bayesian networks (BNs) in environmental human health risk assessment in response to this need. BNs were developed to support causal inference in artificial intelligence applications but are not currently used by environmental regulatory agencies.

First, a proof-of-concept BN is developed to test BN performance in predicting the effect of maternal exposure to arsenic in drinking water on the risk of newborn lower birthweight for gestational age. The network is the first of its kind to model a dose-response relationship connecting an environmental hazard to a human health outcome. In addition, unlike prevailing regulatory risk assessment approaches, it accounts for inter-individual metabolic differences. The BN is shown to outperform current regulatory risk assessment methods in balancing predictive sensitivity and specificity.

Second, a BN is developed to predict the effect of arsenic exposure in drinking water on the risk of diabetes and prediabetes, while accounting for inter-individual differences in arsenic metabolism and body mass index. In addition, the BN's utility to risk managers is demonstrated by using the model to predict the population-level health consequences of reduced arsenic exposure (including decreased diabetes prevalence). These predictions demonstrate the importance of considering both cancer and non-cancer outcomes when making policy. BNs' ability to facilitate cost-benefit calculations in regulatory contexts is highlighted.

Finally, improvements to risk assessment utility by using BNs are illustrated through a model developed to quantify risk to wastewater treatment workers of contracting Ebola virus disease from contact with contaminated wastewater during an outbreak. The model is used to identify key factors affecting risk and captures risk under different mitigation strategies.

These results suggest that BNs offer a quantitatively sophisticated, flexible, and transparent method that addresses key challenges in current risk assessment practice in support of policymaking.

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