Assessing Vulnerability to PFAS Contamination in Michigan

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Introduction

PFAS, as known as per- and polyfluoroalkyl substances, is a dangerous pollutant that has contaminated Michigan's environment. Sources of PFAS are abundant, often from industrial processes and products (Kato et al. 2021). PFAS and its products tend to be highly resistant to environmental degradation and can leach through the hydrologic system to spread contamination. These chemicals tend to bioaccumulate through ingestion and therefore present a danger to both people and the ecosystem through water and food chains (Helmer et al. 2022). The State of Michigan has become a national leader in PFAS monitoring (Helmer et al. 2022) and the Michigan PFAS Action Response Team (MPART) provides this data to the public. Although recent regulations have reduced the presence of certain PFAS, regulations have mostly focused on longer chain PFAS and shorter chain PFAS continue to present a danger, as they are more easily leached (Kato et al. 2021).

Polluted drinking water has been a recurring issue in Michigan, such as the Flint Water Crisis of 2014, so PFAS contamination is of concern for the public health of the state's residents. Some demographic groups may be more vulnerable to PFAS contamination (Kato et al. 2021). Demographics can reflect both geography and wealth, so it may be able to identify certain populations that are at particularly high risk of PFAS contamination. This may be due to patterns of migration, access to healthcare, and the wealth to recover from or prepare for a crisis.

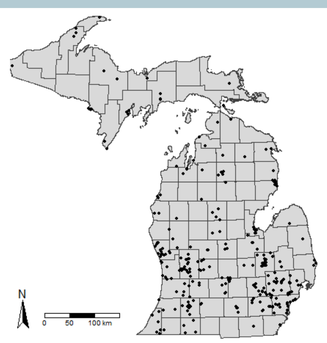

Figure 1: Distribution of PFAS contamination sites across Michigan

Research Questions

- Are PFAS contamination sites distributed randomly throughout Michigan counties?
- Which Michigan counties have an abundance of PFAS contamination sites, compared to their neighbors, that may present greater risk of PFAS exposure?
- Which demographic vulnerability factors are most strongly related to PFAS concentration measurements in a cluster of PFAS contamination?

Methodology

Local Indicator of Spatial Autocorrelation (LISA)

The first task was to perform a local indicator of spatial autocorrelation (LISA) analysis with a first-order queen contiguity to determine if there is a cluster of counties within Michigan that have greater risk of PFAS contamination than their neighboring counties. Two types of PFAS-related variables were chosen and attributed to the counties: number of known sites of PFAS contamination and surface water measurements tested for PFAS concentrations. The first-order queen contiguity accounts for interactions of counties that share only a point, not a border, and ensures each county has at least one interaction.

Spatial Regression Analysis

Next, we conducted a spatial regression analysis to determine if there are any demographic variables indicative of vulnerability that are correlated with PFAS concentration. Demographic data came from the American Communities Survey of 2022. We selected predicting variables that may be indicative of marginalized populations and those with fewer means to protect themselves from PFAS exposure. For example, a community with less access to healthcare through unemployment, poverty, and underinvestment will be less effective at recovering from harm and protecting overall health from future harm. These variables were aggregated to the census tract level for the cluster counties of interest identified by the LISA.

Results

Local Indicator of Spatial Autocorrelation (LISA)

The LISA was performed twice with two different variables. A first-order contiguity matrix was employed to account for interactions between counties whose borders share only a point and not a line. Both versions of the LISA yielded nearly identical results. With a global univariate Moran's I statistic of about 0.015 and a p-value greater than 0.35, we fail to reject the null hypothesis that there is no spatial autocorrelation observed among the counties based on PFAS contamination. The largest high-high cluster contains Monroe, Wayne, Macomb, and Lapeer counties, and overlaps with much of the Detroit metropolitan area. This cluster is the major PFAS contamination region observed in Michigan.

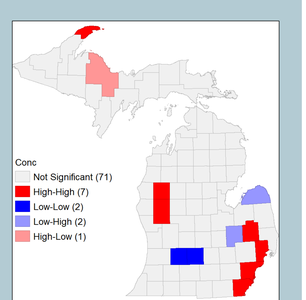

Figure 2: Results of the LISA

Spatial Regression Analysis

The initial independent variables included unemployment, poverty, age 65+, no health insurance, black population, and median income. After checking for multicollinearity, we decided to refine the variables down to black population, median income, and no health insurance. We filtered out any tracts that did not have PFAS concentration data which resulted in many geographic gaps between tracts (Figure 3). We chose to define our neighborhood using the nearest neighbor approach with k=4 since most of the tracts had at least 4 close neighbors. This was chosen over a distance threshold approach because there wasn't a distance that captured the proper neighboring tracts without resulting in an excessive number of sub-groups. The nearest neighbors approach resulted in only 2 distinct sub-group neighborhoods that we manually connected.

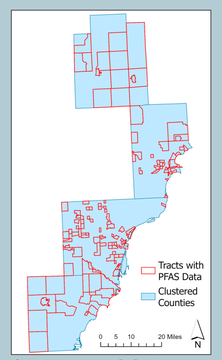

Figure 3: Cluster of counties and their tracts that have PFAS data

The initial ordinary least squares (OLS) regression significant spatial autocorrelation (SAC). We used the Lagrange Multiplier Statistic to assess if an adjusted spatial error or lag model would help eliminate SAC. Both the error and lag models had significance, so we ran both to see which one fit our data better. We decided on the error model because it met the assumptions (no SAC, homoskedasticity) and it had the lowest AIC out of the three model choices. This adjusted model found negative correlation between PFAS concentration and two independent variables: people without health insurance and median income (Table 1).

Table 1: Results of the spatial error regression model.

Variable	Estimate	Std. Error	Z value	Pr (>|z|)
No health insurance (ratio of total pop)	-2.02E+00	9.84E-01	-2.06E+00	0.039
Black population (ratio of total pop)	5.96E-01	6.70E-01	8.91E-01	0.373
Median income ($)	-7.56E-06	3.82E-06	-1.98E+00	0.048

Limitations and Future Research

A major limitation of this study is an under-sampling bias in the available datasets. The PFAS contamination sites are already known to be contaminated, and the dataset does not include any sites that are potentially contaminated and yet undiscovered. The surface water samples are also limited to open waterways and do not include groundwater or drinking water samples. Therefore, a spatial regression analysis was less successful due to discontinuity of the observations in the census tracts. Further analysis may also include new predicting variables. For example, PFAS are commonly leached from landfills and proximity to landfills might suggest greater risk of exposure (Helmer et al. 2022). The historic land use can be an effective suggestion of PFAS contamination, especially considering the automotive industry's deep roots in southeastern Michigan.

Conclusions

The cluster of major PFAS contamination in southeast Michigan can likely be explained with the region's history and hydrology. Southeastern Michigan was a mecca of industry in the twentieth century, especially for automobiles, and experienced immense population growth. In recent decades, the region has economically stagnated but continues to deal with the effects of the industrial boom. The PFAS contamination may be due to the history of industry and accumulation of historic waste in landfills. Furthermore, the only Michigan counties whose watersheds flow into Lake Erie are within this contaminated cluster. The PFAS could have originated inland and leached southeast towards Lake Erie, gradually accumulating in the water table and organisms while resisting degradation.

Higher PFAS concentrations are more likely to be found in lower income areas, which suggests there may be some income inequalities in exposed populations. This result matches our hypothesis that vulnerable populations (e.g. lower income) are more at risk of exposure. Interestingly though, higher PFAS concentrations are also more likely to be found near populations with higher ratios of health insurance. This suggests that these populations are able to be treated for adverse health effects that may result from PFAS.

References

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