

COVID-19 cases reported by NJ municipalities as of 9/24/2020 (i.e., by the end of the "first wave" of the pandemic)

Air Toxics, Environmental Justice and COVID-19: GEOSPATIAL ANALYSES ACROSS NEW JERSEY AND THE US

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NEW JERSEY CLEAN AIR COUNCIL PUBLIC HEARING

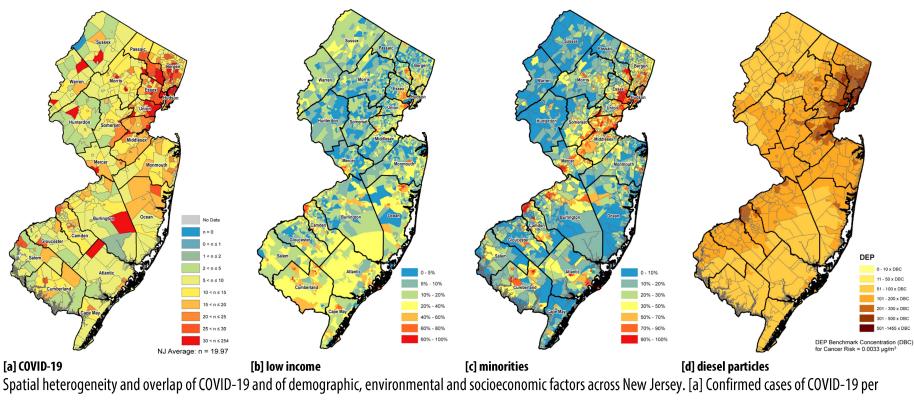
2023-04-19



- Why is it important to understand the relationship between disparities in chronic low-level exposures to Air Toxics and disparities in COVID-19 mortality?
 - Why is it important to understand this relationship in a sociodemographic and environmental justice context?
- Because regulatory decision making for Air Toxics relies on assessments of their potential human health effects
 - **Because** exposures to individual or co-occurring Air Toxics may contribute to increased vulnerability to respiratory infection (and in particular COVID-19) in a cumulative manner
 - Because cumulative exposures are especially relevant for overburdened (e.g., minority) communities and among sensitive populations (e.g., very young children)
- Geospatial Analytics (including Geostatistical and Machine Learning methods) allow quantification of the associations between COVID-19 mortality and chronic exposures to Air Toxics while controlling for other risk factors (environmental, behavioral, sociodemographic)



Spatial Patterns of COVID-19 Spread and of Selected Social and Environmental Determinants of Health across NJ



1,000 population at municipality level (7/23/2020). [b] Percentage of low-income population (<2-times poverty level) at census tract level (2017).[c] Percentage of minority populations at census tract level (2017). [d] Airborne diesel emission particle levels (from the 2014 USEPA National Air Toxics Assessment).

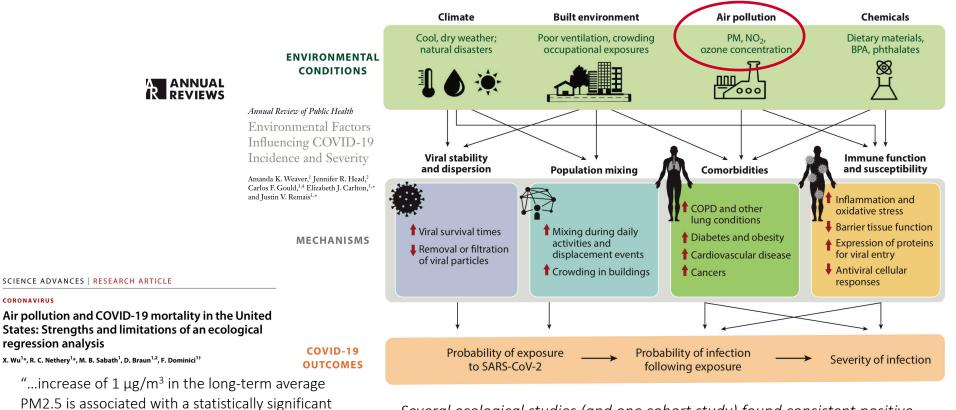


11% (95% CI, 6 to 17%) increase in the county's

COVID-19 mortality rate..."

Numerous Studies Assessed Environmental Factors Influencing COVID-19 Incidence and Severity

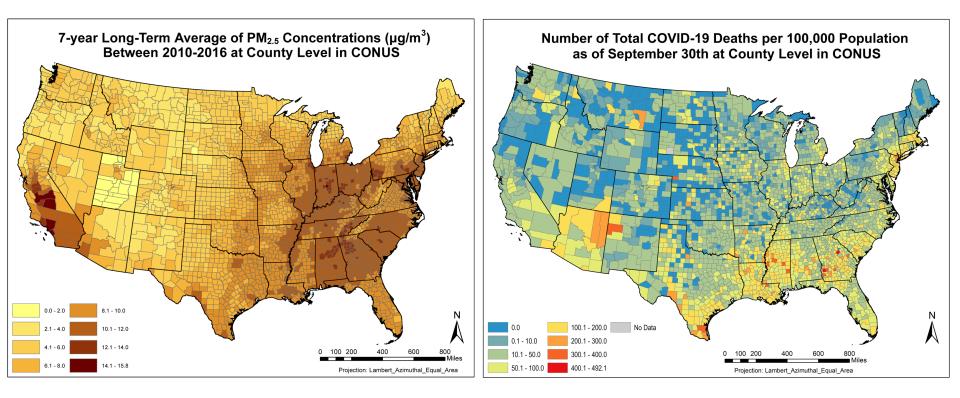
BUT AIR POLLUTION CONSIDERATIONS FOCUSED ALMOST EXCLUSIVELY ON CRITERIA POLLUTANTS



Several ecological studies (and one cohort study) found consistent positive associations of elevated COVID-19 incidence and mortality with past PM2.5 levels; similar associations have been established for NO_2 - but not for O_3



COUNTY-LEVEL CONUS EXPOSURE-WIDE ASSOCIATION ANALYSIS OF COVID-19 FOR THE FIRST WAVE OF THE PANDEMIC (MARCH TO SEPTEMBER 2020)



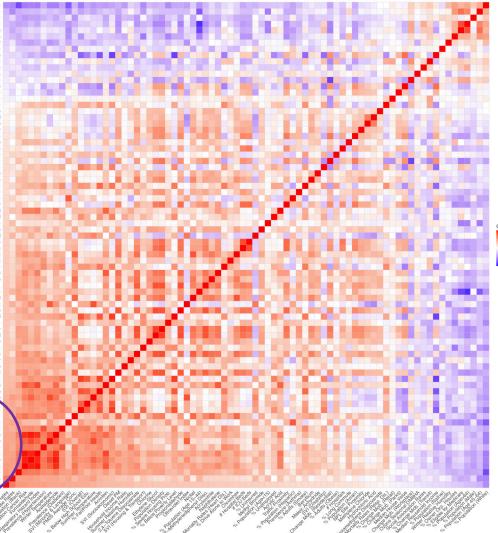


COVID-19 EXPOSURE-WIDE ASSOCIATION STUDY-CONUS

Correlations of the numbers of confirmed COVID-19 case and death rates with a range of Demographic, Environmental and Socioeconomic (DES), behavioral and health factors for the 3,092 CONUS counties (as of September 30, 2020)

- The Spearman Correlation Matrix summarizes our results from an Exposure-Wide Analysis that considered a range of DES/H factors (76 shown):
 - the matrix has been ordered, so COVID-19 cases are presented in the first (bottom) row; the closer the rows of the other variables are to the bottom row, the higher is their correlation with the number of confirmed COVID-19 cases

% Population (Age 45-64) % Population (Male) % Population (Age>64) % Eligible for Medicare % Owner Occ. Houses Winter Relative Humidity % Population (Native) Median Household Income 6 Change Mob. (Transit) Social Association Rates Ozone Seasonal DM8HA 6 Change Mob. (Workplace) Median House Value % Change Mob. (Parks) % Change Mob. (Retail) Mortality Bates (Besp. Dis.) Hexamethylene Diisocyanate Hydrochloric Acid Methylene Chloride NPL Site Proximity % Population (Asian) % Long Commute # Hosnitals % Adults (Obese) % Change Mob. (Residential) SVI (Disability) Maleic Anhydride Beryllium % Adults (Smoke) Prevalence (Asthma) % Population (Hispanic) Traffic Proximity Acrylic Acid % Unemployed Population (Age<15) Methyl Bromide % Uninsured # ICU Beds # Hospital Beds Chromhex % Drive Alone to Work Mortality Rates (Heart Dis.) Naphthalene Acrylonitrile 4P-Methylenediphenyl Diiso. % Population (Age 15-44) Nickel Ultraviolet Index Pronionaldehude % Below Poverty Level 6 Severe Housing Prob Population Density Ethylene Glycol Chloring SVI (Housing & Transport) 2,4-Toluene Diisocyanate Summer Relative Humidity Household Income Ratio Diesel PM SVI (Socioeconomic Acrolei SVI (Overall PM25 Average Conc. SVI (Minority & Language) Prevalence (Diabetes) Acetaldehyde Winter Temperature revalence (Hypertension) espiratory Hazard Index Formaldehyde nhalation Cancer Risk % Population (Black) COVID19 Case Rates OVID19 Death B:





- Two Studies Assessed in A Systematic Manner the Impact of Air Toxics on COVID-19 Outcomes - Nationwide (CONUS) County-Level Study by SUNY (Petroni *et al.,* 2020)
- New Jersey Statewide Municipality-Level Study by Rutgers (Ren et al., 2023)
- Both studies implemented hierarchical statistical models, relating COVID-19 mortality to chronic individual and cumulative exposures to Air Toxics, while controlling for individual pollutants and multiple known environmental, demographic, and socioeconomic risk factors
 - Considered both the combined respiratory Hazard Index (HI) and individual respiratory Hazard Quotients (HQ) for specific Air Toxics
 - Formaldehyde, acetaldehyde, acrolein, naphthalene, and diesel PM were selected because they are, on average across the US, the top contributors to respiratory HQs (collectively they account for over 50% of the total US respiratory HI in 2014)
 - Since most Air Toxics levels have been decreasing over time, the NATA modeled estimates of concentrations and respiratory HQs for 2014 were used to approximate the average levels between the years 2010 and 2019
 - Our (Rutgers) study systematically evaluated consistency and robustness of findings using six alternative Geostatistical models and two Machine Learning models

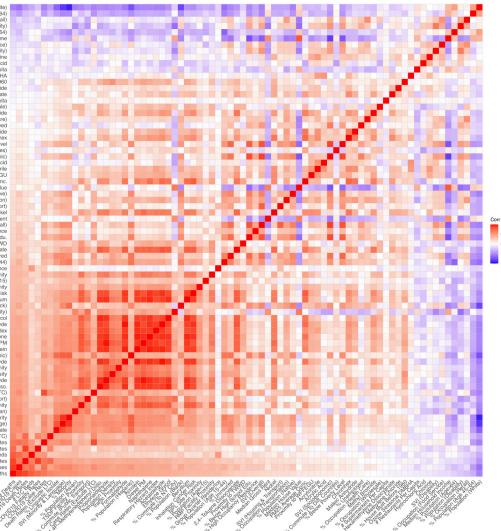


COVID-19 EXPOSURE-WIDE ASSOCIATION STUDY – NJ

Correlations of the numbers of confirmed COVID-19 cases and deaths with a range of Demographic, Environmental and Socioeconomic (DES) factors for the 565 municipalities of New Jersey

- The Spearman Correlation Matrix summarizes results from our Exposure-Wide Analysis that considered a range of DES factors:
 - the matrix has been ordered, so COVID-19 cases are presented in the first (bottom) row; the closer the rows of the other variables are to the bottom row, the higher is their correlation with the number of confirmed COVID-19 cases

% Population (White) % Population (Age 45-64) % Occupation (Retail) % Population (Disability) % Population (Age>64) Median Household Income Occupation (Food Service) SVI (Disability) Chlorine Hydrochloric Acid # Restaurants Per Capita Ozone Seasonal DM8HA % House Built Before 1960 Methylene Chloride Hexamethylene Diisocvanate # Supermarkets Per Capita Occupation (Wholesale) Methyl Bromide % Occupation (Health Care) % Unemployed Maleic Anhydride Chromhey % Below Poverty Level % Commute (To Diff. Counties) SVI (Socioeconomic) Acrylic Acid Acrylonitrile Proximity to WFFEGU PM25 Average Conc Median House Value % Population (Native) % Occupation (Transportation) SVI (Housing & Transport) Nicke Median Gross Rent SVI (Overall) % High Occupancy Residence % Below High School Edu Proximity to TWWD 2,4-Toluene Diisocyanate % Uninsured % Population (Age 15-44) % Group Quarter Residence **RMP Facility Proximity** % Population (Age<15) NPL Site Proximity Inhalation Cancer Risk Bervllium % Population (Black) % Commute (To NY City) Ethylene Glycol Acetaldehvde Respiratory Hazard Index Naphthalene Diesel PM Acrolein % Population (Hispanic) Formaldehyde Traffic Proximity Population Density Propionaldehvde 4.4P-Methylenediphenyl Diiso. Case Rates (Exclude LTC) % Commute (Public Transport) **TSDF** Facility Proximity % Population (Asian) % Minority SVI (Minority & Language) % Linguistic Isolate Death Rates (Exclude LTC) COVID19 Case Rates COVID19 Fatality Rates # LTC Beds COVID19 Death Rates # COVID19 Cases # COVID19 Deat

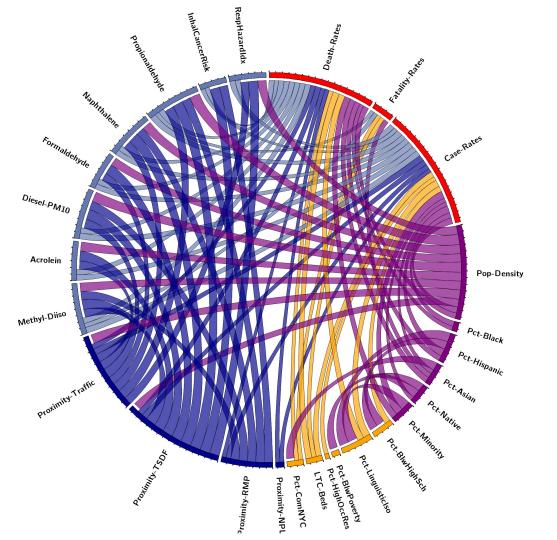




COVID-19 EXPOSURE-WIDE ASSOCIATION STUDY – NJ

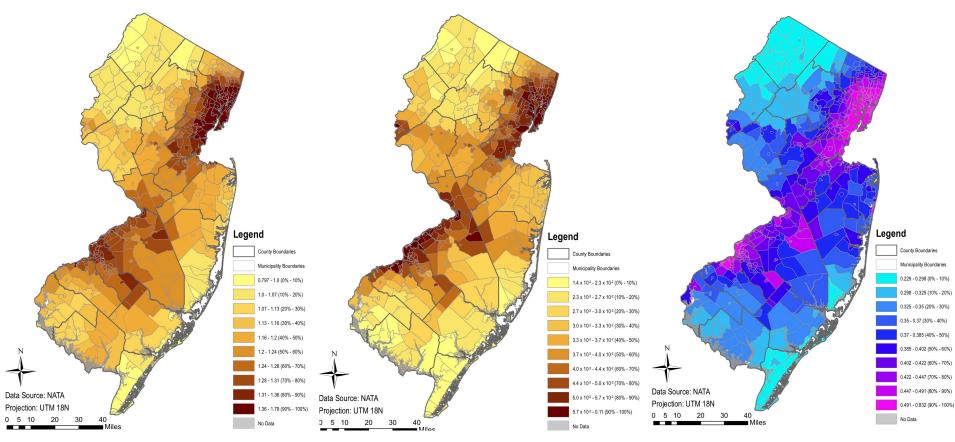
Correlations of the numbers of confirmed COVID-19 cases and deaths with a range of Demographic, Environmental and Socioeconomic (DES) factors for the 565 municipalities of New Jersey

• The Spearman Correlation Chord Plot provides an alternative visual representation of our Exposure-Wide Analysis: only factors with Spearman correlation values > 0.3 are included in this plot





LEVELS OF AIR TOXICS ACROSS THE 565 NJ MUNICIPALITIES (MID-2010S)



Formaldehyde (RfC = $9.8 \,\mu g/m^3$)

Naphthalene (RfC = $3 \mu g/m3$)

Respiratory Hazard Index (HI)



COVID-19 MORTALITY RATE RATIO CHANGE BY AIR POLLUTANT FOR NJ AND THE US

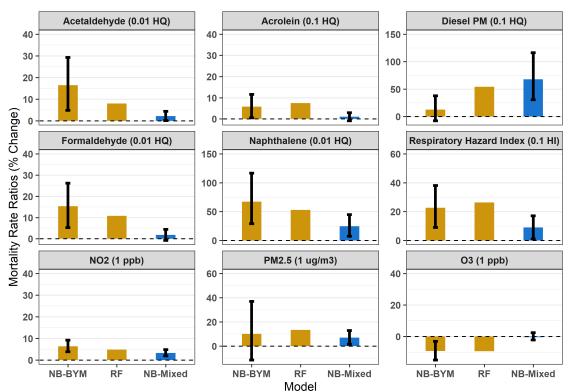
Study Area



Expected % change in COVID-19 MRR per added pollutant unit with 95% confidence interval

NJ results from the best performing geostatistical and machine learning models are compared here with national results from other studies for their consistency

- Increase of $1 \,\mu g/m^3$ in PM2.5 concentration is associated with a 10.7% (-16.6%, 47.0%) MRR increase in NJ
- Very small increases in chronic levels of respiratory air toxics are associated with significant increases in MRR
- 10% increase in Air Toxics Respiratory HI is ٠ associated with >20% MRR increase (NJ)
- 1% increase in Formaldehyde HQ is ٠ associated with >10% MRR increase (NJ)
 - These increases in MRR occur for • levels of Air Toxics much lower than their chronic respiratory hazard RfCs



RF: Random Forest Machine Learning model; NB-Mixed: Negative Binomial Mixed Effects Model NB-BYM: Negative Binomial Besag-York-Mollie Model; HI: Hazard Index; HQ: Hazard Quotient



- Chronic exposures to Air Toxics at low levels below their chronic non-cancer reference concentrations (RfC) may heighten population vulnerability to COVID-19
 - Statistically significant associations of both individual and cumulative chronic Air Toxics exposures with county-level COVID-19 mortality have been found for CONUS
 - Statistically significant associations of both individual and cumulative chronic Air Toxics exposures with municipality-level COVID-19 mortality have been found for New Jersey
 - Though the studies assessing associations of Air Toxics exposures with COVID-19 have limitations, as they primarily rely on modeled estimates and aggregated data, they demonstrate robust consistency in findings both nationwide and for New Jersey
- Exposures to Air Toxics are higher in overburdened communities, where many other environmental, demographic and socioeconomic factors represent additional risks leading to adverse COVID-19 outcomes



- The potential links between chronic exposures to Air Toxics and COVID-19 mortality should be considered when evaluating the efficacy of pollution prevention strategies
 - The plausible biological mechanisms (Adverse Outcome Pathways) that may increase vulnerability to COVID-19 due to chronic Air Toxics exposures are also potentially relevant to other infections and respiratory diseases
 - The fact that statistically significant associations of disparities in COVID-19 mortality with disparities in individual and cumulative chronic exposures to Air Toxics are found for low levels and small increases of their concentrations, should inform policy making
- Expanded monitoring of Air Toxics, including focused studies involving local and personal monitoring in overburdened communities, should be considered in order to reduce uncertainties in the assessment of health risks and improve chemical risk management and public health policy



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Data

 Multiple Organizations sharing/exchanging information on COVID-19; a (very) partial list includes: CDC (COVID-19, WONDER, SVI); USEPA (NATA, NEI, TRI, EJScreen); USCB (COVID-19, ACS); USBL; AHRQ; NJDOH; NJDEP; the Models of Infectious Disease Agent Study (MIDAS); the JHU CSSE dashboard; the COVID Tracking Project (The Atlantic); the NY Times GitHub repository; Christoph Schoenenberger; the Yu group (Berkeley); the Mordecai group (Stanford); Google mobility data; the Unacast SD scoreboard; NJ local health departments and NJ media

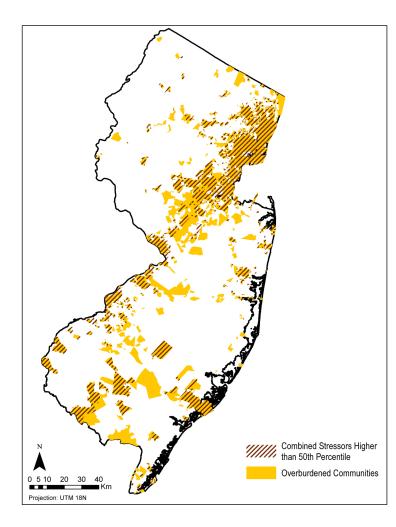


SUPPLEMENTARY SLIDES



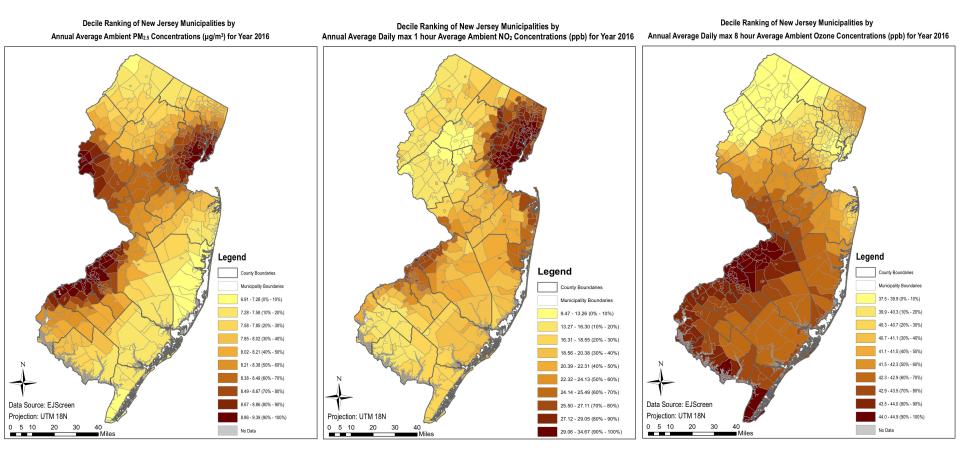
FROM NJDEP EJMAP

Overlap of overburdened communities with areas where combined stressors are above the 50th percentile statewide



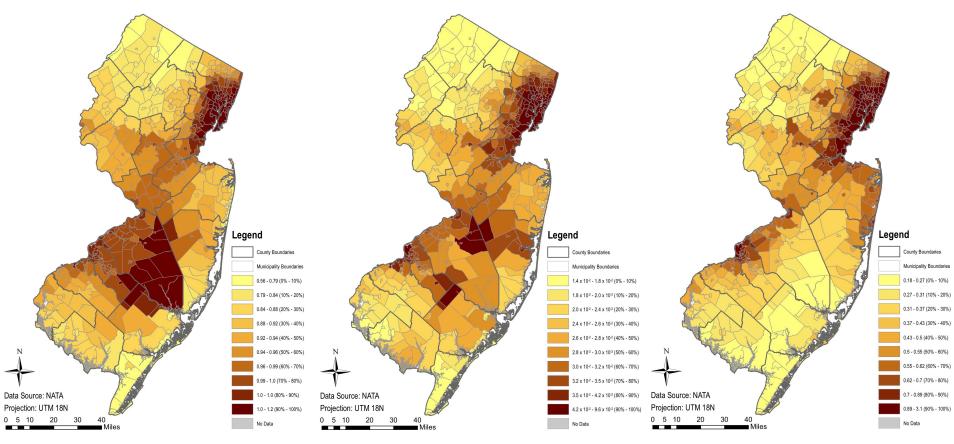


LEVELS OF CRITERIA POLLUTANTS ACROSS THE 565 NJ MUNICIPALITIES (2016)





LEVELS OF AIR TOXICS ACROSS THE 565 NJ MUNICIPALITIES (MID-2010S)



Acetaldehyde (RfC 9 μ g/m³)

Acrolein (RfC 0.035 μ g/m³)

Diesel PM (RfC 5 μg/m³)



Correlation analysis ----- Identify pairwise association patterns using heatmaps (correlation matrices) and chord plots.

Determine initial variable set based on expert knowledge and public concerns.

Variable forward selection (from candidate variable set) algorithm: (1) Pearson correlation < 0.6; (2) Variance inflation factor < 5; (3) Minimum Deviance Information criterion (DIC).

Examine stability of estimated confidence intervals via inclusion of multiple covariates; Check variable consistency with Poisson distribution and Negative Binomial distribution frameworks.

Consider six representative modeling approaches: Poisson regression, Poisson Mixed Effect Model, Poisson Besag-York-Mollie Spatial Model, Negative Binomial regression, Negative Binomial Mixed Effect model, and Negative Binomial Besag-York-Mollie Spatial Model.

Apply non-informative prior to parameters and hyperparameters; Compare Bayesian inference estimates Developed using INLA (Integrated Nested Laplace Approximation) to Frequentist inference estimates.

Each one of the remaining variables is added to the base model for statistical analysis; Highly correlated variables are removed in the model to avoid unstable results.

Estimate death rates for townships where death number is not available; Evaluate model efficiency by comparing predicted and reported death number at county level: the predicted county-level death number is the sum of predicted deaths for relevant townships.

COVID-19 Exposure-Wide Association Study - NJ Variable selection &

stability analysis

Base model construction

& Bayesian inference

with INLA

Estimate credible intervals

for variables not included

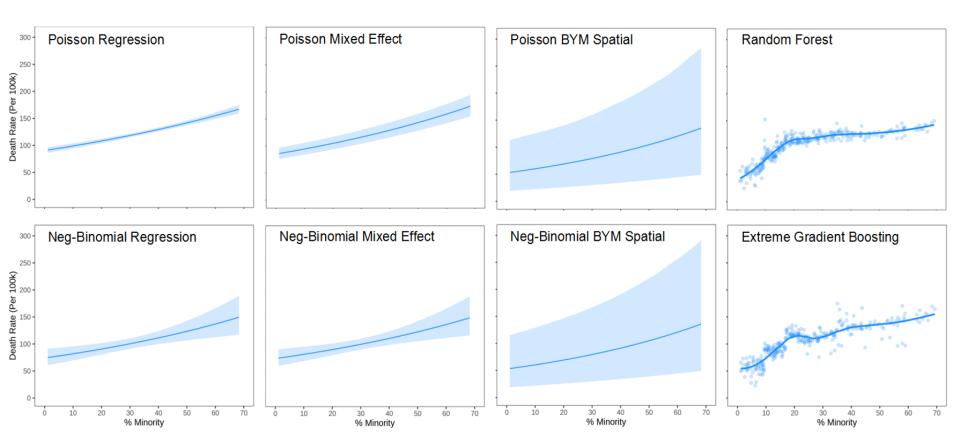
in base model

Prediction & validation

A multivariate Bayesian spatial statistical modeling framework for quantifying local effects of environmental and socioeconomic and factors on COVID-19 outcomes



Example results (% Minority vs COVID-19 Death Rate) Across All NJ Municipalities FROM Six Geostatistical and Two Machine Learning Models



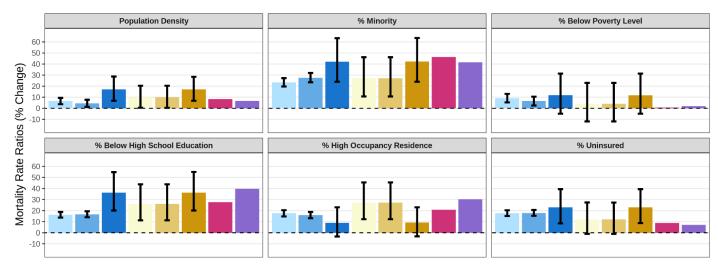


COVID-19 MORTALITY RATE RATIO CHANGE FOR SELECTED SOCIAL FACTORS AT MUNICIPALITY LEVEL ACROSS NJ

Expected % change in COVID-19 MRR per standard deviation of the factor with 95% confidence interval

Interpretation:

- A standard deviation increase (23.4%) in % minority is associated with 42.3% (24%, 63.6%) increase in mortality rate;
- a standard deviation increase (6.3%) in % below high school education is associated with 36.3% (20.1%, 55%) increase in mortality rate
 (Ren *et al.*, 2023)



Estimates from six statistical or geostatistical and two machine learning models were compared to assess consistency of results

