Environmental Impact of Water and Air Contaminants on Public Health

Astrid-Ines Foamkom
The University of Texas Rio Grande Valley, astridines.foamkom01@utrgv.edu

Luis A. Peña Marquez
The University of Texas Rio Grande Valley, luis.penamarquez01@utrgv.edu

Maria Sophia Malbas
The University of Texas Rio Grande Valley, mariasophia.malbas01@utrgv.edu

Esmeralda Rodriguez
Texas Commission on Environmental Quality, esmeralda.rodriguez@tceq.texas.gov

Noe Garza
The University of Texas Rio Grande Valley, noe.garza@utrgv.edu

See next page for additional authors

Author Information

Astrid-Ines Foamkom, Luis A. Peña Marquez, Maria Sophia Malbas, Esmeralda Rodriguez, Noe Garza, and Ney Alliey-Rodriguez

Astrid-Ines Foamkom
06/27/2024

Title: Environmental Impact of Water and Air Contaminants on Public Health

Authors: Astrid-Ines Foamkom[1], Luis Peña Marquez[2], Maria Sophia Malbas[2], Esmeralda Rodriguez[3], Dr. Noe Garza[2], Dr. Ney Alliey Rodriguez[2]
Affiliations: 1: University of Texas Rio Grande Valley School of Medicine; 2: University of Texas Rio Grande Valley Institute of Neuroscience; 3: Texas Commission on Environmental Quality

Abstract:
Background
Established literature suggests a strong relationship between exposure to air contaminants and physical health. Similarly, numerous studies have demonstrated the effects of water pollution on public health. Texas denizens are often victims of poor air and water quality, yet there are scant studies that have integrated evidence of health tolls caused by air and water pollution across the state. In this study, we assessed the relationship between particulate matter <2.5 micrometer ($PM_{2.5}$), water contaminants (inorganic compounds and Total Dissolved Solids), and health conditions.
Methods
The study used data from the 2018 Medicare and Medicaid report which displayed chronic health conditions across all counties in Texas. Additionally, the study also includes collected data on Bromoform, Nitrate and Total Dissolve Solid concentrations from different water systems provided by the Texas Commission on Environmental Quality Public Drinking Water Watch annual reports. Out of 251 Texas counties, complete data was only available from 28 counties representing different quadrants of this state.
Results
The annual average of $PM_{2.5}$ concentration throughout Texas in 2018 ranged from 4.61 to 10.68 mg/m^3. $PM_{2.5}$ was positively associated with Alzheimer's disease/Dementia occurrence ($r = 0.587$). Similar correlations were also observed with chronic kidney disease ($r = 0.594$), COPD ($r = 0.418$), hyperlipidemia ($r = 0.683$), hypertension ($r = 0.463$), ischemic heart disease ($r = 0.441$), osteoporosis ($r = 0.613$), and stroke ($r = 0.493$). For water contaminants, Bromoform and Nitrates had no significant correlations with any health conditions. Concerning Total Dissolved Solids (mg/L), the results showed a positive trend with Alzheimer's disease/Dementia ($r = 0.583$), heart failure, and ischemic heart disease ($r = 0.402$). Surprisingly, Total Dissolved Solids displayed a negative correlation with cancer ($r = -0.641$) and a moderate association with chronic kidney disease ($r = 0.397$).
Conclusion
While this analysis lacks certain controls, the associations between the variables observed warrant a significant improvement in the overall quality and continuous monitoring of the state of Texas' public drinking water sources and regional air.

Introduction

Air and water are essential resources for human survival. According to Lara Cushings and colleagues, water insecurity is a major concern for millions of people in the United States, with elevated levels of improper infrastructure and running water insecurities plaguing disadvantaged populations (Cushing et al., 2023). Similarly to water, good air quality is a universal human right, yet air quality severely lacks in certain parts of the United States, including Texas. One major factor of this uneven distribution is socioeconomic status. People with lower socioeconomic status are more exposed to hazardous air pollutants (van den Brekel et l., 2024). These pollutants come from traffic, proximity to plants, and even home life (Hajat et al., 2015).

Long term exposure to air quality contaminants such as fine particles, PM2.5, has been identified as a major factor for poor health due to air. According to the Asthma and Allergy Foundation of America, air quality index (AQI) over 100 is deemed unhealthy for sensitive populations such as people with COPD and asthma. Elevated levels of fine particulates and ozone in the outdoor air causes increased flairs in patients with these respiratory conditions, which in turn, aggravates their illnesses further (Altman et al., 2023). The same can be said for increased indoor particulates, especially in homes where noxious fumes are continuously inhaled (Hajat et al., 2015). Be it outdoors or indoors, frequent exposure to fine particulate matter is hazardous to sensitive populations for it leads to increased hospitalizations and respiratory complications (Bryan and Landrigan, 2023).

However, linking water pollution to health concerns is not as linear (Schwarzenbach et al., 2010). While it is safe to assume water contaminants correlate with numerous diseases, identifying which factor of water pollution is the cause is quite difficult (Schwarzenbach et al., 2010; Bondy and Campbell, 2017). Numerous studies have suggested water quality from groundwater or surface water can be affected by running agriculture, environmental runoffs, natural disasters, and other factors such as power plants, and oil refineries (Lu et al., 2015; Schwarzenbach et al., 2010; Schaider et al., 2019). Others have suggested rapid urbanization has put pressures on the water supply, deteriorating water quality surrounding the urban landscape in the process (Ren et al., 2014; Aitkenhead-Peterson et al., 2011). Traditional pollutants such as heavy metals, (e.g., lead and mercury), inorganic compounds (e.g., arsenic, nitrates, etc.) and bacteria are directly from runoffs and irrigation (Levin et al., 2024). These pollutants circulate around Texas waters and have further implications for human health. In fact, O'Bryant and colleagues explored the potential association between current and long-term arsenic exposure and detailed neuropsychological functioning in a sample of rural-dwelling adults and elders in Cochran county, and the results of the study showed that GIS-based groundwater arsenic exposure (current and long-term) was significantly related to poorer scores in language, visuospatial skills, and executive functioning (O'Bryant et al., 2011). Other studies confirmed equivalent results. Pollutants such arsenic and nitrate and metals, especially mercury, are linked to cancer and immunodeficiency conditions in adults and children (Levin et al., 2024; Rios-Arana et al., 2004). Furthermore, like with air pollution, people with lower economic stability are often more susceptible to these harmful chemicals (Briggs et al., 2008; Schaider et al., 2019). The lack of proper management of water distribution being one of the main worries for impoverished areas. For instance, colonias, especially those in Lower Texas, are victims of water depreciation, contamination, and poor distribution (Olmstead, 2004; Wutich et al., 2022). As a universal right, it is important to ensure water quality is maintained properly regardless of location.

Few studies have integrated the effects of air and water contamination on chronic conditions. This study attempts to identify how certain environmental variables (Bromoform, Total Dissolved Solids, Nitrates, and PM2.5) correlate with conditions such as Alzheimer's disease/Dementia, chronic obstructive pulmonary disease (COPD), hypertension and more. Here we conduct a series of exploratory analyses, aimed to determine correlations between air pollution from $PM_{2.5\ \text{and}}$ water contaminants like nitrate and total dissolved solids, which may show some positive associations with diseases across all measured variables.

Methods

2.1 Medicare-Medicaid Report and Chronic Conditions

We obtained 2018 Medicare-Medicaid data for Texas. This report is a county-based data summary of Alzheimer's disease and related dementias, chronic kidney disease, COPD, depression, heart failure, hyperlipidemia, hypertension, ischemic heart disease, osteoporosis, and stroke. In total, 251 Texas counties were available from this source.

2.2 Air Quality Data and PM2.5

The Daily Air Quality Reports, developed by the Environmental Protection Agency (EPA), were utilized in this study. The evaluation of the Texas Commission for Environmental Quality (TCEQ) air stations did not account for all counties regional station summations. Because of this, we decided to use the Daily Air Quality reports which operates on a daily time step and can display all measured air pollutants across a continuous range by county. Among the 251 counties surveyed, only 28 counties had annual daily recordings of fine particulate matter, $PM_{2.5}$. Fine particulate matter is composed of solid and liquid particles that circulate in the air because of discharge and industrial emissions. $PM_{2.5}$ concentrations vary throughout locations, e.g., Texas, due to regional climate, emissions, air molecule dispersion patterns. Therefore, monitoring PM data is critical for proper air quality.

The annual average threshold, according to the EPA, for fine particulate matter (PM2.5) is 9 micrograms per cubic meter. This threshold was used to evaluate counties air pollution levels. An average of the continuous data from the Daily Air Quality reports were measured and correlated with 2018 Medicare/Medicaid Report. Covariates that could be potential confounders were absent based on the 2018 report and the air quality report. If the data permitted, socio-demographic factors such as age range, gender, health behaviors (e.g., smoking habit and alcohol intake) and regional distribution of socio-economic factors would have been included (Mortamais et al., 2020).

2.3 Water Quality

Public drinking water systems in Texas, according to the TCEQ, utilize either groundwater or surface water for their water supply and distribution. The water is treated and pumped to different municipalities based on location. Several water systems are based within one county, but only a few distribute water across large areas. Data on conductivity, pH, temperature, Total Dissolve Solids (TDS), dissolved oxygen, metals, organic and inorganic compounds are measured by each water system across counties and records are sent to the TCEQ Public Drinking Water watch, which then display data from each water sampling site according to county served. We surveyed the TCEQ Public Drinking Water Watch for major water systems across all 28 selected counties and recorded their data from the year 2018 on the following variables: Total Dissolved Solids, metals (Lead and Copper), and chemical compounds: Arsenic, Nitrate, Sulfate, and Bromoform. Unfortunately, not all surveyed water system sites contained the mentioned variables thus we decided to focus on Bromoform, Total Dissolved Solids, and Nitrate given established literature (Nguyen, 2018; Schaider et al., 2019)

2.3.1 Water Quality Variables: Nitrates, Bromoform, and Total Dissolved Solids

Each variable has a standard designed to protect people from environmental hazards and public harm in accordance with the Safe Drinking Water Act and drinking water requirements for states and public water systems (EPA.gov). All water systems across the country must follow said water quality standard established by the EPA. For nitrate, 10 mg/L is the maximum concentration limit (MCL). Although there is no established maximal concentration, according to the EPA, water systems should aim for a value of zero for trihalomethanes such as bromoform and bromodichloromethane. Total Dissolved solids (TDS) is a measure of dissolved compounds. TDS should not exceed 500 milligrams per liter to preserve water quality as elevated concentrations can precipitate health complications (Fewtrell and Bartram, 2001; Boyd, 2020).

Because many water system reports had multiple recordings, data was recorded with the following caveats. If either variable had values less than the threshold aka “reporting level” (e.g., mg/L <0.01 or <0.1), then the value will be converted to zero. If a variable had a "concentration value" (i.e., measured level at or above threshold), then said value was recorded. If multiple concentration values were present, then an average value would be measured. This was done to ensure an objective analysis of the data.

2.4 Statistical Analysis

For the study, a Pearson's correlation was conducted to assess both PM2.5 and water quality parameters (Bromoform, Nitrates, and Total Dissolved Solids) per established literature (Nguyen et al., 2023). The correlation coefficient, r, ranges from +1 to -1, with a coefficient of + indicating a positive correlation between variables and - indicating a negative correlation. Any correlation above 0.40 was considered significant.

Results

**Here we report a work-in-progress. The current approach is based on available data therefore the variables will not contain a p value. Further details will be included in the future.*

The annual average of $PM_{2.5}$ concentration throughout the evaluated 28 counties ranges from 4.61 — 10.68 mg/m3. There is a positive association between Alzheimer's disease/Dementia occurrence and PM2.5 concentration (r = 0.587). Interestingly, similarly high correlation between PM2.5 and chronic kidney disease (r = 0.594), *COPD (r = 0.418)*, hyperlipidemia (r = 0.683), hypertension (r = 0.463), ischemic heart disease (r = 0.441), osteoporosis (r = 0.613), and stroke (r = 0.493) were also observed as displayed by Table 1.

Table 1

Correlation Table for Fine Particulate Matter ($PM_{2.5}$) and Chronic Health Conditions

	Alzheimer's Disease/Dementia	Asthma	Cancer	Chronic Kidney Disease	COPD	Depression	Heart Failure	Hyperlipidemia	Hypertension	Ischemic Heart Disease	Osteoporosis	Stroke
Average $PM_{2.5}$	0.588	0.119	0.184	0.594	0.412	0.239	0.266	0.683	0.463	0.441	0.613	0.493

Certain counties had Bromoform levels above the safety parameters set by the EPA. Likewise, the same counties had TDS values exceeding the 500 mg/L limit as shown on Table 2.

Table 2

Counties with elevated TDS and Bromoform concentrations for 2018

County	Total Dissolved Solids (mg/L)	Bromoform Concentration (mg/L)
Bexar	400	1.82
Bowie	122	0.167
Cameron	730.57	5.23
Ector	982	23.91
El Paso	552.92	2.84
Hidalgo	665	11.58
Jefferson	149.57	0.0
Kleberg	1015.84	0.43

TDS correlated with Alzheimer's disease/Dementia (r = 0.583), cancer (r = -0.641), heart failure (r = 0.402), and ischemic heart disease (r = 0.402). The negative correlation with cancer was unexpected and warrants further investigation. Additionally, there is a mild association between chronic kidney disease and

TDS (r = 0.397). For Bromoform and Nitrate, surprisingly, there were no strong associations between the water contaminants and the evaluated chronic conditions. These results also warrant further investigation.

Discussion

This paper explores the potential relationship between air and water pollution and chronic conditions. The results demonstrate a strong correlation between both pollution and Alzheimer's disease/Dementia. This association was expected to be given current epidemiological evidence supporting acute and long-term $PM_{2.5}$ exposure is positively linked to Dementia and Alzheimer's disease (Tsai et al., 2019). Despite the strength of the association, Alzheimer's disease and Dementia are not necessarily inherited conditions, rather an ensemble following natural and environmental causes (National Institute of Aging, 2021). This study recommends evaluating APOE4 genetic susceptibility, a common genetic feature observed in Alzheimer's patients, and present diagnoses with a control for age and gender and socioeconomic status when evaluating the potential causality of $PM_{2.5}$ to Alzheimer's disease and other neurodegenerative disorders (Tsai et al., 2019).

Unexpectedly, there was no correlation between asthma and $PM_{2.5}$ despite numerous studies demonstrating the negative relationship between $PM_{2.5}$ and asthma (Gavett and Koren, 2001; Lavigne et al., 2021; Baek et al., 2020). Asthma is a common chronic respiratory condition triggered by hyper inflammatory reactions following exposure to allergens such as pollen, dust mites and exhaust particles (Baldacci et al., 2015). Given the nature of $PM_{2.5}$ in the atmosphere, it was expected that the results would demonstrate a moderate association between asthma prevalence across the counties and $PM_{2.5}$ concentration, but that was not the case. Another study using similar statistical methods and the EPA county wide $PM_{2.5}$ data noted similar findings (Gorai et al., 2016). Given this, it may be worth exploring distinct types of air pollution to evaluate possible confounding factors at play such as ozone and nitric oxide.

Particulate matter has been known to exacerbate COPD since patients with COPD are at risk of more hospitalizations if ambient $PM_{2.5}$ is not reduced (Zhu et al., 2020). The association, however negative, can be curbed by lifestyle as shown by Kim and colleagues. Their study demonstrated how daily habits such as maintaining good ventilation and incorporating clean filters can help reduce the negative effects of $PM_{2.5}$ on people with COPD (2023). However, such effects only work when indoor $PM_{2.5}$ is the main concern. The same cannot be said for outdoors given environmental unpredictability. Mortality is high in patients with COPD in areas with elevated PM2.5 (Chen and Hoek, 2020). This is incredibly concerning for elderly people and those of lower socioeconomic status since they are victims of their environment. That is why it is important to implement proper air quality measures.

Particulate pollution has been associated with cardiovascular diseases, and though epidemiologic evidence has been mixed on the subject, increases in annual $PM_{2.5}$ concentration do correlate with increased odds of hypertension (Brook et al., 2009). This result is also seen when analyzing air pollution and hyperlipidemia. One study explored these findings in Chinese adults and found that for every 10 microgram/m^3 increase in ambient $PM_{2.5}$, there was an increase odd ratio of hypertension of 1.14 (Lin et al., 2017). Nevertheless, the increase is not linear as factors of location and metabolic condition were not clear. Regardless, they observed that areas, regardless of population size, with higher $PM_{2.5}$ displayed elevated prevalence of hypertension. Another study done in Toronto displayed similar findings. After exposing participants to different air contaminants in controlled settings, the results demonstrated that particulate matter, not ozone nor other air contaminants, was responsible for increased diastolic pressure and induced proinflammatory pathways. For hyperlipidemia, a study on ambient PM2.5 exposure measured blood lipid-related indicators across 197,957 participants. Parallel to Lin and colleagues, a 10 microgram/m^3 increase correlated with an increase in low-density lipoprotein cholesterol concentration and total cholesterol concentration (Liu et al., 2023). Although this study did not explore real-time $PM_{2.5}$ exposure, the results of the cited studies highlight the importance of air quality, especially for sensitive populations. Further research will be conducted in the future regarding the link between hypertension, hyperlipidemia, and air pollution.

Exposure to Bromoform can occur following consumption of treated drinking water. In Texas, filtration and treatment often includes chlorinated water which if ingested long term can affect the liver, kidney, and central nervous system. Bromoform is considered a carcinogen with some studies linking levels of the contaminant with liver and intestinal tumors (Agency for Toxic Substances and Disease Registry, 2005). This conclusion though is not set since the findings behind Bromoform mostly concern non-cancer effects such as renal toxicity and hepatic lesions (Verma and Ray, 2024). Furthermore, according to the EPA, most people would have to consume 7.9×10^3 mg/kg-day daily for cancer risk and 1.79 x 10(1) mg/kg-day (EPA.gov; Agency for Toxic Substance and Disease Registry, 2005). As a byproduct of how Texas water systems clean their water and given its capacity for harm, Bromoform levels established by the EPA should be upheld across the state of Texas. Despite its' lack of conclusive evidence for cancer, it is still a carcinogen, and better precautions should be taken to ensure a low number of incidents.

Though there is no evidence of a statistically significant correlation between nitrates and chronic health conditions, the relationship between the variables warrants further exploration. Ingestion of nitrates has been shown to result in cancer, birth complications and other adverse effects (Mirvish, 1995; Ward et al., 2018) Though found in multiple food, nitrate will runoff from agricultural sources and leech out of the soil and into the surrounding ground waters (Ward et al., 2005). This is potentially harmful to humans who, if not treated properly, can lead to the complications mentioned. Still, threshold levels of nitrates are often never reached in Texas, which may explain the lack of associations. It is also important to note how low nitrate levels are in Texas despite the rate of pollution around the area. The state averages 4.6 mg/L in nitrate levels with rare occasions resulting in elevated concentrations (Ward et al., 2018). While the value of nitrate is significant, most studies of water nitrate levels and cancer and other diseases implement regional water sources, and most importantly, water consumption history (2018). The latter is the most important and most difficult yet highly predictive of cancer risk. The current study could not have measured that so future works on nitrate concentrations and health risks associated should analyze for water consumption in homes and public spaces on top of measuring nitrate values. This way, the analysis and results between nitrates and chronic condition will be more dependable and accurate than the present data.

Limitations

The study is not yet complete. It will require an additional assessment of further water contaminants and their corresponding data. We may change focus based on the given variables, and instead of focusing across the state, we will focus on comparing the results between Lower Rio Grande Valley counties versus the rest of Texas. This may include adding Starr and Willacy to the list of counties to observe. Additionally, data from the EPA was used and it may not be reflective of the state. We may explore data from the TCEQ and look at the location of the active stations and their annual records on $PM_{2.5}$, ozone, and nitric oxide levels. Lastly, since we did not assess actual samples, it is difficult for a time-based analysis, but with the current conditions, this is not warranted given the plethora of collected water and air data statewide.

Acknowledgements

We thank Esmeralda Rodriguez and Dr. Noe Garza for their time and assistance. We also thank Francisco Martinez for his valuable comments on water management and quality inspection.

References

1. Altman, M. C., et al. (2023). Relationships of outdoor air pollutants to non-viral asthma exacerbations and airway inflammatory responses in urban children and adolescents: a population-based study. *The Lancet Planetary Health*, DOI: 10.1016/PIIS2542-5196(22)00302-3.
2. Aitkenhead-Peterson, J. A., Nahar, N., Harclerode, C. L., & Stanley, N. C. (2011). Effect of urbanization on surface water chemistry in south-central Texas. *Urban Ecosystems*, *14*, 195-210.
3. Baek, J., Kash, B. A., Xu, X., Benden, M., Roberts, J., & Carrillo, G. (2020). Association between ambient air pollution and hospital length of stay among children with asthma in South Texas. *International journal of environmental research and public health*, *17*(11), 3812.
4. Baldacci, S., Maio, S., Cerrai, S., Sarno, G., Baïz, N., Simoni, M., Annesi-Maesano, I., Viegi, G., & HEALS Study (2015). Allergy and asthma: Effects of the exposure to particulate matter and biological allergens. *Respiratory medicine, 109*(9), 1089–1104. https://doi.org/10.1016/j.rmed.2015.05.017
5. Bondy, S. C., & Campbell, A. (2017). Water Quality and Brain Function. *International journal of environmental research and public health, 15*(1), 2. https://doi.org/10.3390/ijerph15010002
6. van den Brekel, L., Lenters, V., Mackenbach, J. D., Hoek, G., Wagtendonk, A., Lakerveld, J., Grobbee, D. E., & Vaartjes, I. (2024). Ethnic and socioeconomic inequalities in air pollution exposure: a cross-sectional analysis of nationwide individual-level data from the Netherlands. *The Lancet. Planetary health*, *8*(1), e18–e29. https://doi.org/10.1016/S2542-5196(23)00258-9
7. Briggs, D., Abellan, J. J., & Fecht, D. (2008). Environmental inequity in England: small area associations between socio-economic status and environmental pollution. *Social science & medicine (1982), 67*(10), 1612–1629. https://doi.org/10.1016/j.socscimed.2008.06.040
8. Brook, R. D., Urch, B., Dvonch, J. T., Bard, R. L., Speck, M., Keeler, G., Morishita, M., Marsik, F. J., Kamal, A. S., Kaciroti, N., Harkema, J., Corey, P., Silverman, F., Gold, D. R., Wellenius, G., Mittleman, M. A., Rajagopalan, S., & Brook, J. R. (2009). Insights into the mechanisms and mediators of the effects of air pollution exposure on blood pressure and vascular function in healthy humans. *Hypertension (Dallas, Tex.: 1979), 54*(3), 659–667. https://doi.org/10.1161/HYPERTENSIONAHA.109.130237
9. Bryan, L., & Landrigan, P. (2023). PM2.5 pollution in Texas: a geospatial analysis of health impact functions. *Frontiers in public health, 11*, 1286755. https://doi.org/10.3389/fpubh.2023.1286755
10. Boyd, C. E., & Boyd, C. E. (2020). Dissolved solids. *Water Quality: An Introduction*, 83-118.
11. Chen, J., & Hoek, G. (2020). Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. *Environment international*, *143*, 105974. https://doi.org/10.1016/j.envint.2020.105974
12. Cushing, L., Dobbin, K. B., et al. (2023, October 12). "Water Insecurity And Population Health: Implications For Health Equity And Policy, " *Health Affairs Health Policy Brief*. DOI: 10.1377/hpb20230921.68748
13. Drinking Water Regulations and Contaminants (2023). In EPA.gov. Retrieved June 26, 2024, from https://www.epa.gov/sdwa/drinking-water-regulations-and-contaminants
14. Fewtrell, L., & Bartram, J. (Eds.). (2001). Water quality: guidelines, standards & health. IWA publishing.
15. Gavett, S. H., & Koren, H. S. (2001). The role of particulate matter in exacerbation of atopic asthma. *International archives of allergy and immunology, 124*(1-3), 109–112. https://doi.org/10.1159/000053685
16. Gorai, A. K., Tchounwou, P. B., & Tuluri, F. (2016). Association between Ambient Air Pollution and Asthma Prevalence in Different Population Groups Residing in Eastern Texas, USA. *International journal of environmental research and public health, 13*(4), 378. https://doi.org/10.3390/ijerph13040378

17. Hajat, A., Hsia, C., & O'Neill, M. S. (2015). Socioeconomic Disparities and Air Pollution Exposure: a Global Review. *Current environmental health reports*, *2*(4), 440–450. https://doi.org/10.1007/s40572-015-0069-5
18. Han, I., Whitworth, K. W., Christensen, B., Afshar, M., An Han, H., Rammah, A., Oluwadairo, T., & Symanski, E. (2022). Heavy metal pollution of soils and risk assessment in Houston, Texas following Hurricane Harvey. *Environmental pollution (Barking, Essex: 1987), 296*, 118717. https://doi.org/10.1016/j.envpol.2021.118717
19. Lavigne, É., Talarico, R., van Donkelaar, A., Martin, R. V., Stieb, D. M., Crighton, E., Weichenthal, S., Smith-Doiron, M., Burnett, R. T., & Chen, H. (2021). Fine particulate matter concentration and composition and the incidence of childhood asthma. *Environment international, 152*, 106486. https://doi.org/10.1016/j.envint.2021.106486
20. Levin, R., Villanueva, C. M., Beene, D., Cradock, A. L., Donat-Vargas, C., Lewis, J., ... & Deziel, N. C. (2024). US drinking water quality: exposure risk profiles for seven legacy and emerging contaminants. *Journal of exposure science & environmental epidemiology*, *34*(1), 3-22.
21. Lin, H., Guo, Y., Zheng, Y., Di, Q., Liu, T., Xiao, J., Li, X., Zeng, W., Cummings-Vaughn, L. A., Howard, S. W., Vaughn, M. G., Qian, Z. (Min), Ma, W., & Wu, F. (2017). Long-Term Effects of Ambient PM2.5on Hypertension and Blood Pressure and Attributable Risk Among Older Chinese Adults. *Hypertension*, *69*(5), 806–812. https://doi.org/10.1161/hypertensionaha.116.08839
22. Liu, Q., Wang, Z., Lu, J. et al. Effects of short-term PM2.5 exposure on blood lipids among 197,957 people in eastern China. Sci Rep 13, 4505 (2023). https://doi.org/10.1038/s41598-023-31513-y
23. Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A. J., Jenkins, A., Ferrier, R. C., Li, H., Luo, W., & Wang, T. (2015). Impacts of soil and water pollution on food safety and health risks in China. *Environment international, 77*, 5–15. https://doi.org/10.1016/j.envint.2014.12.010
24. Mirvish, S. S. (1995). Role of N-nitroso compounds (NOC) and N-nitrosation in etiology of gastric, esophageal, nasopharyngeal and bladder cancer and contribution to cancer of known exposures to NOC. *Cancer letters*, *93*(1), 17-48.
25. Mortamais, M., Gutierrez, L. A., de Hoogh, K., Chen, J., Vienneau, D., Carrière, I., ... & Berr, C. (2021). Long-term exposure to ambient air pollution and risk of dementia: Results of the prospective Three-City Study. *Environment international*, *148*, 106376.
26. National Institute On Aging. (2021, July 8). What is Alzheimer's Disease? *National Institute on Aging*. United States. Retrieved from https://www.nia.nih.gov/health/alzheimers-and-dementia/what-alzheimers-disease.
27. Nguyen, G. (2018). The Water Isn't Safe: The Dismal State of Texas Drinking Water Regulation.
28. O'Bryant, S. E., Edwards, M., Menon, C. V., Gong, G., & Barber, R. (2011). Long-term low-level arsenic exposure is associated with poorer neuropsychological functioning: a Project FRONTIER study. *International journal of environmental research and public health*, *8*(3), 861-874.
29. Olmstead, S. M. (2004). Thirsty colonias: Rate regulation and the provision of water service. *Land Economics*, *80*(1), 136-150.
30. Ren, L., Cui, E., & Sun, H. (2014). Temporal and spatial variations in the relationship between urbanization and water quality. *Environmental science and pollution research international, 21*(23), 13646–13655. https://doi.org/10.1007/s11356-014-3242-8
31. Rios-Arana, J. V., Walsh, E. J., & Gardea-Torresdey, J. L. (2004). Assessment of arsenic and heavy metal concentrations in water and sediments of the Rio Grande at El Paso-Juarez metroplex region. *Environment international, 29*(7), 957–971. https://doi.org/10.1016/S0160-4120(03)00080-1
32. Schaider, L. A., Swetschinski, L., Campbell, C., & Rudel, R. A. (2019). Environmental justice and drinking water quality: are there socioeconomic disparities in nitrate levels in U.S. drinking water? *Environmental health: a global access science source*, *18*(1), 3. https://doi.org/10.1186/s12940-018-0442-6

33. Schwarzenbach, R. P., Escher, B. I., Fenner, K., Hofstetter, T. B., Johnson, C. A., von Gunten, U., & Wehrli, B. (2006). The challenge of micropollutants in aquatic systems. *Science* (New York, N.Y.), *313*(5790), 1072–1077. https://doi.org/10.1126/science.1127291
34. Tsai, T. L., Lin, Y. T., Hwang, B. F., Nakayama, S. F., Tsai, C. H., Sun, X. L., Ma, C., & Jung, C. R. (2019). Fine particulate matter is a potential determinant of Alzheimer's disease: A systemic review and meta-analysis. *Environmental research*, 177, 108638. https://doi.org/10.1016/j.envres.2019.108638
35. Toxicological Profile for Bromoform and Dibromochloromethane. Atlanta (GA): Agency for Toxic Substances and Disease Registry (US); 2005 Aug. 3, HEALTH EFFECTS. Available from: https://www.ncbi.nlm.nih.gov/books/NBK597977/
36. Verma, M., & Ray, S. D. (2024). Bromoform. *Encyclopedia of Toxicology, 2,* 301-305, https://doi.org/10.1016/B978-0-12-824315-2.00943-X
37. Ward, M. H., DeKok, T. M., Levallois, P., Brender, J., Gulis, G., Nolan, B. T., & VanDerslice, J. (2005). Workgroup report: drinking-water nitrate and health—recent findings and research needs. *Environmental health perspectives*, *113*(11), 1607-1614.
38. Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., Villanueva, C. M., & van Breda, S. G. (2018). Drinking Water Nitrate and Human Health: An Updated Review. *International journal of environmental research and public health*, *15*(7), 1557. https://doi.org/10.3390/ijerph15071557
39. Wutich, A., Jepson, W., Velasco, C., Roque, A., Gu, Z., Hanemann, M., ... & Westerhoff, P. (2022). Water insecurity in the Global North: A review of experiences in US colonias communities along the Mexico border. *Wiley Interdisciplinary Reviews: Water*, *9*(4), e1595.
40. Zhu, R. X., Nie, X. H., Chen, Y. H., Chen, J., Wu, S. W., & Zhao, L. H. (2020). Relationship between particulate matter (PM2.5) and hospitalizations and mortality of chronic obstructive pulmonary disease patients: a meta-analysis. *The American journal of the medical sciences*, *359*(6), 354-364.