Title

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Effect of Water Contamination Levels on Public Health Outcomes on Children, Infants & Minority Populations in California

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Abstract

Keywords: contamination, marginalized, disparities, thyroid cancer, public health risks

Water contamination remains a pressing public health issue across the world with disproportionate impacts on vulnerable populations. The study focuses on Northern and Southern California with an emphasis on Central Valley, California. By analyzing the effects that water contamination levels have on infants, children, and marginalized communities, the research can address the gap between societal impacts and public health outcomes that water contamination constitutes. More specifically, the processes of mitigation efforts and health policies that focus on more equitable access to safe drinking water.

Consideration of current trends and data address that low-income school districts disproportionately neglect water cleanse. Inadequate investment and lack of resources within underprivileged communities play a significant role with the correlation between high nitrate contamination and thyroid cancer in the Central Valley. Additionally, the results reveal the significant variations between regions regarding high cases of thyroid cancer due to water contamination and disproportionate exposure among marginalized groups. Despite limitations, this study aims to inform future policy decisions and promote more equitable water safety standards across California. By exploring the disconnect between environmental contamination and resulting health outcomes, highlighting the urgent need for equitable solutions. Analyzing existing mitigation strategies and health policies, the research underscores regional disparities in water quality and inequities in exposure from bureaucratic inefficiencies and policy gaps exacerbating public health risks. While acknowledging certain limitations, the research provides

valuable insights to support future policy development and advocate for more inclusive and access to safe drinking water throughout California.

Introduction

Water contamination affects everything, from human populations to the surrounding organisms and environment, and even the economy through its consequences. As technology has continued to develop, pollution has been increasing, and contamination is starting to affect populations at a larger and more disproportionate scale. Water contamination is defined as water contaminated by any physical, chemical, biological or radiological substance (United States Environmental Protection Agency, 2024). To measure water contamination in general we use the Water Quality Index (WQI) which summarizes large amounts of water quality data into a score from 1-100 and higher scores indicate cleaner and less contaminated water (United States Environmental Protection Agency, 2021). The WQI is useful for identifying the general cleanliness of the water but it does not do a great job at identifying the type of contamination prevalent in the specific water. Another study was conducted to determine the ranges of WQI that indicate different levels of contamination. A score from 80-100 indicates high water quality and that the water rarely exceeds guidelines, maybe only by a minimal margin, a score of 70-79 indicates fair water quality that sometimes exceeds guidelines by a wide margin, and a score below 69 indicates poor water quality that often exceeds guidelines by a wide margin. Poor water quality impacts all people, especially infants (ages 0-1 years old), and can disproportionately impact marginalized populations—populations of people who experience discrimination and social, economic, and/or political exclusion due to their race, ethnicity, gender, sexual orientation or socioeconomic status. Water contamination often occurs in areas that are residential, industrial, agricultural, and/or commercial (Environmental Protection Agency, 2024). Spills or releases from industrial waste, leaking from septic systems, leaking from petroleum storage systems, or rain moving pesticides and other chemicals into the nearby water all contribute to water contamination. Furthermore, microorganisms, including bacteria, viruses, and parasites pollute our water and cause those who drink microorganism infected water to have gastrointestinal illnesses and infections. Nitrate and nitrate are present in chemical fertilizers, regular fertilizers, sewage, and animal waste. This contamination causes methemoglobinemia or "blue baby syndrome" that reduces the body's ability to carry oxygen. It is especially serious for infants. Water contamination is a problem because all living organisms need water to survive and contaminated water is linked to diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid, and polio (World Health Organization, n.d.). These are all preventable health risks manageable by access to clean water. These illnesses can lead to death without access to medical care and money to pay for care. According to the World Health Organization "Some 1 million people are estimated to die each year from diarrhoea as a result of unsafe drinking-water, sanitation and hand hygiene. Yet diarrhoea is largely preventable, and the deaths of 395 000 children aged under 5 years could be avoided each year if these risk factors were addressed" (World Health Organization, 2023).

Contamination can occur in many ways, whether it's metalloid contamination, like arsenic, or agricultural, through nitrate leaching. These pollutants pose serious health risks, from acute illnesses to chronic diseases and long-term developmental issues. Tools like the Water Quality Index (WQI) and guidelines from the National Environmental Quality Standards (NEQS) and the World Health Organization (WHO) help measure contamination levels and assess the safety of drinking water (see Figure 1). These contaminants have significant public health consequences, causing sickness or spreading diseases. The effects of water contamination are becoming more present in local and national studies, prompting the need for legislative action to slow its effects and search for regulations to target its spread, including specific incidents of pollution and large-scale non-point source contamination. Water contamination is also a socioeconomic issue concerning equal access to safe drinking water as areas of high contamination are correlated with lower socioeconomic and minority populations. However, there is a lack of large scale research to put direct data towards this correlation. This paper aims to evaluate the effect of water contamination on public health between Northern and Southern California by comparing two similar counties at both the contamination level as well as the social impacts of such contamination and address any possible association between the two.

The EPA has a “Contaminant Candidate List,” which prioritizes contaminants for research to focus on and for funds to be allocated towards. Recently, some organic contaminants have been noted as emerging, specifically regarding water contamination. Methyl Tertiary-butyl ether (MTBE) was used as “a gasoline additive to improve air quality,” but has recently been found in surface and groundwater supplies from boating and underground water storage leakage. Another contaminant of note is that of pesticides, including “Fonofos, Dimethoate, Terbufos, Fulfone, and Terbacil.” Finally, Nitrogenous compounds are extremely toxic and tend to be found in water, specifically nitrogenous disinfection by-products (DBPs). The American Water Works Association mentions that N-DBPs have been “found to be carcinogenic and/or mutagenic.” In response, WHO has placed restrictions on the levels that are understood as “safe,” specifically in drinking water. All of these contaminants can affect California in different ways. As these emerging contaminants are mass-produced in industry settings or recreationally, they only increase levels in water sources throughout California. For instance, California is largely coastal and has many large recreational lakes where MTBEs will increase their concentrations, as well as California's large agricultural industry regularly uses pesticides and additional fertilizers that can contribute to environmental decay and groundwater pollution. Finally, DBPs are regularly used inside the homes, and if not properly used or disposed of, they can also contribute to contamination. Overall, these emerging contaminants point to a worrying trend of the continuation of contamination in most industries in California. [1]

Methodology

This study employs a literature review methodology to assess the impact of water contamination on public health in California, with a focus on children, infants, and minority populations. The research prioritizes peer-reviewed studies, government reports, and institutional research published within the past 10 years to ensure relevance and accuracy. Data sources include PubMed, Google Scholar, and government databases such as the California State Water Resources Control Board and the Environmental Protection Agency (EPA).

The study examines major contaminants, including arsenic, nitrates, and lead, which have been linked to significant health risks such as developmental disorders, gastrointestinal diseases, and increased cancer risks. Through a comparative analysis of Northern and Southern California, the research identifies disparities in contamination levels and their disproportionate impact on marginalized communities. This includes an assessment of local policies, enforcement effectiveness, and socioeconomic factors influencing exposure levels.

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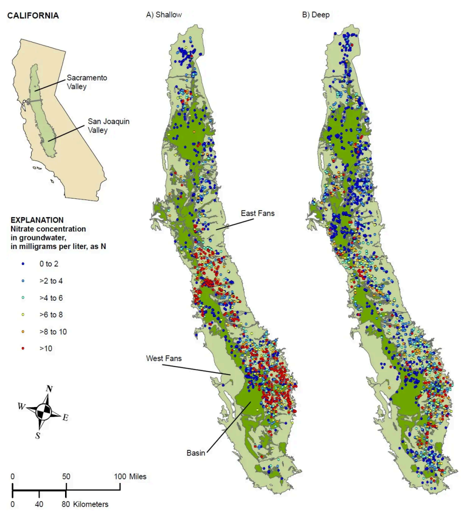
[1] AWWA Organic Contaminants Control Committee. 2008. "Emerging Organic Contaminants: What Are They?" *Opflow* 34 (1): 16–17. https://www.jstor.org/stable/opflow.34.1.16.

Key limitations of this study include data gaps, inconsistencies in regional data collection methods, and challenges in establishing direct causation between contamination and health outcomes. Additionally, variability in local regulations and enforcement may further complicate comparative analysis and contribute to disparities in water quality standards across areas. Vulnerable populations—particularly infants, children, and low-income communities—often lack adequate access to healthcare and live far from research centers, making them difficult to reach and underrepresented in research studies. Insufficient research on early-life and cumulative exposures further limits understanding of long-term health impacts.

Despite these limitations, the research aims to provide a comprehensive overview of water contamination's health effects, supporting policy development and advocating for equitable access to clean water across California—especially for underserved and high-risk populations. Future directions include community-engaged research, portable sensor technologies, and federal investment to improve data collection and ensure equitable access to clean water.

Results

Water contamination in California reveals significant disparities. It disproportionately affects marginalized communities, particularly low-income and minority populations. Hoague et al. (2022) found that drinking water in Watts, predominantly African American and Latino neighborhood in Los Angeles, contained lead levels exceeding EPA safety thresholds in several public housing developments. The study highlighted how aging infrastructure and systemic disinvestment contributed to persistent environmental injustices in the community. This contamination is linked to aging infrastructure, inadequate investment in water system improvements, and systemic neglect in historically under-resourced areas. Similarly, in Northern California, the Oakland Unified School District's own reports have indicated elevated lead levels in school drinking water, prompting concerns about the safety of over 45,000 students (I. Araraso et al., 2006). Nearly 200 drinking fountains and faucets tested above safety limits, raising concerns about the lack of transparency and accountability in public institutions (*People*). The failure to address water contamination in schools and residential communities disproportionately affects children, who are particularly vulnerable to the developmental and cognitive impacts of lead exposure.



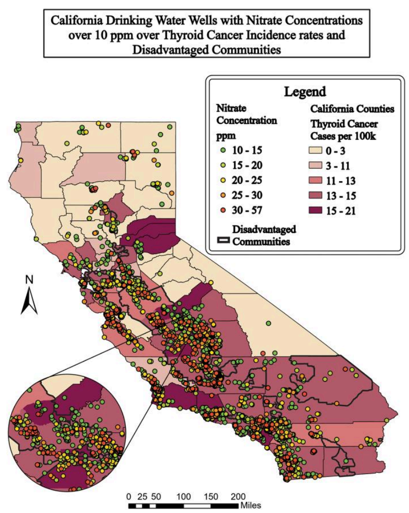
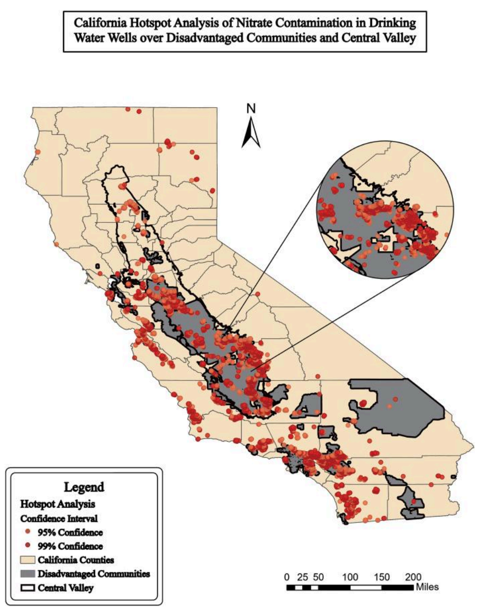


Figure 1 (Left): Map of nitrate concentrations in California's Central Valley groundwater. Red areas exceed the EPA's 10 mg/L nitrate limit. Adapted from (Ransom et al., 2017). **Figure 2** (Right): California Drinking Water Wells with Nitrate Concentrations over 10ppm over Thyroid Cancer Incidence rates and Disadvantaged Communities. Adapted from (Tariqi & Naughton, 2021).

Figure 1 and 2 represent the distribution of nitrates across California drinking water. Figure 2 directly shows the pervasiveness of nitrates in the groundwater, highlighting in red the areas that are above the EPA's limit of 10 mg/L. It identified a correlation between contaminated groundwater and highly agricultural areas in the Central Valley. Figure 3 (below) represents a case study investigating the effect of nitrate well contamination per county in California in correlation to thyroid cancer in the Central Valley compared to other counties in California. Nonparametric tests were utilized since there was a non-normal distribution where each county had thyroid cases per 100,000 compared with the percentages of exceeding 5 and 10 ppm nitrate.



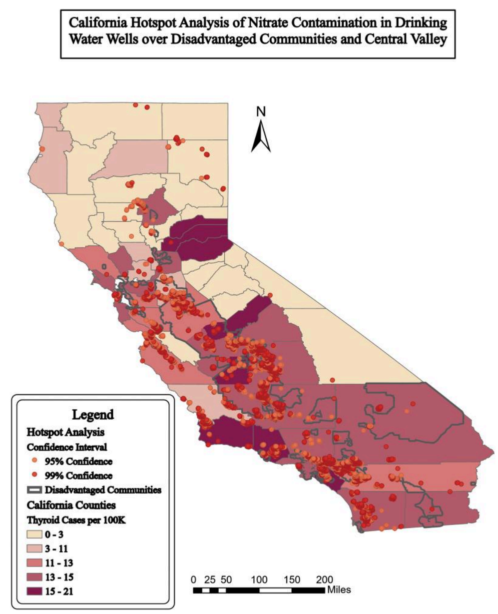


Figure 3 (Left:) California Hotspot Analysis of Nitrate Contamination in Drinking Water Wells over Disadvantaged Communities and the Central Valley. **Figure 4** (Right): California Hotspot Thyroid Cancer of Nitrate Contamination in Drinking Water Wells over Disadvantaged Communities in the Central Valley.

Moreover, there are remarkable disparities in water contamination between Northern and Southern California. In Northern California, nitrate contamination is spread widely in rural areas because the process of farming may enhance the nitrate concentration in wells in private households, particularly in the Central Valley. Recent research by Tariqi and Naughton (2021) found that elevated nitrate levels in groundwater were statistically correlated with higher thyroid cancer incidence, especially in disadvantaged communities where concentrations exceeded 10 ppm. The study analyzed data from the California Cancer Registry and the California Water Boards to do so; this resulted in well data revealing a "statistically significant correlation between nitrate contamination in drinking water and thyroid cancer incidence" (Tariqi & Naughton, 2021). The study specifically found disadvantaged communities (DACs) had higher numbers of nitrate-contaminated wells (called "hotspots"), but also exhibited thyroid cancer rates that were double those of non-DACs (Tariqi & Naughton, 2021). This shows a considerable correlation between negative impacts from water contamination, specifically on the disadvantaged groups in the Central Valley in Northern California. Thus, runoff from agricultural practices is a primary source of contamination impacting groundwater and directly impacts disadvantaged communities more than others.

Figure 4 shows a hotspot analysis of nitrate contamination in drinking water wells in California alongside the data on thyroid cancer incidence rates and the geographic boundaries of disadvantaged communities. There is a critical spatial overlap between areas of high nitrate contamination, elevated thyroid cancer rates shaded in darker tones, and socially vulnerable populations, suggesting that there exists a compounded environmental health risk in marginalized areas. Moreover, the darker red dots representing a 99% confidence interval present statistically significant clusters of nitrate contamination, and they are mostly concentrated in the

Central Valley. Figure 5 illustrates the percentage of private wells exceeding the maximum contaminant level (MCL) for nitrates across California counties. Among the blue and green regions with higher incidences of exceedance, the darkest blue indicates areas with over 3% of tested wells surpass the MCL. These are mainly located in the Central Valley and Northern California, overlapping with the contamination hotspots and cancer distribution in Figure 4. The two figures demonstrate the water contamination disproportionately impacting disadvantaged communities and reinforce its connection with nitrate pollution in private drinking water sources.

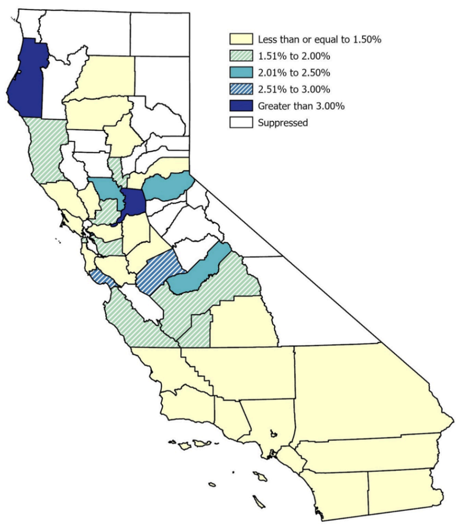


Figure 5: Percent of Children Under 6 Years Old with a Blood Lead Level of 4.5µg/dL or Greater, by California Local Health Jurisdiction, 2020

In Southern California, there is lead contamination in urban areas because of the outdated infrastructure, such as water distribution systems without both financial and policy support from the government, mostly occurring in minority neighborhoods. Johnston and Hricko (2017) reported that neighborhoods with high proportions of Black and Latino residents in Los Angeles exhibited elevated blood lead levels in children due to corroding water pipes and inadequate infrastructure maintenance. Lead, arsenic, and nitrate are the major contaminants, but their impacts on health differ. Lead is commonly found in aging water pipes in urban areas, which is associated with cognitive, behavioral, and developmental disorders in children (Bellinger, 2004). When people have long term exposure to arsenic, they have a greater risk of developing skin, cardiovascular, and molecular diseases such as cancer (Naujokas et al., 2013).

The presence of arsenic is often unmonitored in private wells, particularly in unincorporated rural areas, posing hidden risks to underserved populations. Nitrate will also decrease oxygen transportation in blood and cause methemoglobinemia, especially at the stage of infants.

Additionally, the Imperial Valley in Southern California faces similar issues, but with different contaminants and obstacles. A study by Elvis Xu focusing on the Salton Sea, a known example of eutrophication from high levels of nitrates and its tributaries, found that residents near the sea are being exposed to airborne toxic dust as the lake recedes, uncovering contaminated sediments laced with heavy metals and pesticides. This has led to increased rates of asthma and bronchitis, especially among young children. This contamination has largely reached the lake because of its tributaries carrying agricultural runoff, urban waste, and industrial discharges into the Sea. In 2012, the sea exceeded many risk thresholds with pollutants like selenium, pesticides, nitrates, PCBs, and more.

Discussion

Water contamination disproportionately affects members of low-income and minority communities in California. These socioeconomic groups tend to live in similar areas and more rural areas, which contribute to the lack of focus and updated infrastructure in their water systems. This is shown most prominently through our research of nitrate concentration, specifically in private households. Because water infrastructure poses multiple obstacles, financially and via safety standards, many people in the Central Valley may choose to get their water, only for it to be contaminated by leaching from agricultural fields nearby. Lead, found in aging water pipes, produces a similar problem where underrecognized groups suffer higher and sustained exposure to lead-contaminated water because of bureaucracy and racial injustice in urban areas. Finally, arsenic harm requires more long-term exposure but is known to cause chronic illness and cardiovascular disease. All of these contaminants greatly affect human development, meaning that pregnant individuals who consume these contaminants can indirectly harm their child and put it at risk for many cognitive and behavioral disorders, as well as physical disorders. This risk only perpetuates system contamination that continues to not be addressed, and the only common factor seems to be underrepresented groups, whether it be in rural or urban areas, and even Northern versus Southern California. It is implied that there may be a lack of education and specific push for changes against these contaminants in government, and therefore, changes are not being made without local movements and money to push solutions.

These cases highlight a broader pattern of environmental injustice in California, where low-income communities and communities of color face higher exposure to contaminated water while receiving fewer resources for mitigation and prevention. The geographic disparities between Northern and Southern California suggest systemic inequalities in infrastructure maintenance and enforcement of water safety regulations. Furthermore, the lack of timely communication and intervention in these cases demonstrates how bureaucratic inefficiencies and policy gaps exacerbate public health risks. Without targeted action, these communities remain at greater risk of long-term health consequences, reinforcing cycles of economic and social disadvantage. These findings underscore the urgent need for improved water monitoring, stronger regulatory enforcement, increased investment in infrastructure, and equitable policy reforms to ensure access to safe drinking water across all communities in California.

Besides these health impacts of contaminants in Northern or Southern California, public policy and environmental justice also play a critical role in implementing interventions and researching solutions. Firstly, many underserved communities remain uninformed about the negative impacts of water contamination due to delayed governmental responses and lack of public transparency. This is an example in the Oakland Unified School District, where lead levels exceeding 5 parts per billion were found in nearly 200 drinking fountains across over 1,000 sites, possibly affecting over 45,000 students while families have not been issued by the timely notification (Salazar, 2025). Second, even though some regions have enforced water regulations, the rate of compliance is still unpromising. For example, there are many regulatory exemptions in agriculture in the Central Valley, while the renovation of infrastructure is delayed in the southern part due to a lack of funding and bureaucratic inertia (California Environmental Protection Agency [CalEPA], 2022). As a result, the future policy should focus more on the improvement of infrastructure in neighborhoods with low socioeconomic income and high risk of being affected by inadequate filtration water systems. Also, the officials should strengthen monitoring and make updates more transparent to raise people's awareness through a better contamination reporting system. In addition to researching the influence of climate change, including wildfires and other extreme weather, in exacerbating poor water quality. Emerging threats such as disinfection by-products (DBPs), which are mutagenic or carcinogenic, should also be addressed (American Water Works Association [AWWA], 2023). These studies are rather limited, however, using only a small sample to generalize across Northern and Southern California, a very large and diverse area. However, the rest of our information is an overview concerning contaminants and their prevalence in California as a whole, pointing to very similar trends across the data, especially concerning specific groups and areas that fly under the radar and have very high levels of contamination. This information is helpful, though, because it means that the issue does not need to be a complete restructuring of the water system in California to make a concrete difference. Only some areas need to receive direct aid and infrastructure updates immediately, whereas the rest of the focus can be spent on addressing sources of nonpoint pollution, like nitrate leaching in agriculture.

It is also important to consider the ethics of contamination that leads to degrading human health as well as future studies. For example, the study by Elvis Xu doesn't directly measure the health effects of these specific contaminants on people as it focuses much more broadly. It calls out the significant impacts of this contamination on the lake and the environmental considerations are not okay for humans to be ingesting. The resuspension of contaminated sediments due to wind and receding water levels is currently the most obvious outcome, but the pervasive character of the contaminants may reveal further effects in the future. This points to the differences between Northern and Southern California, although the situations and issues with agricultural interference are similar. Further studies can build upon our work by continuing to identify specific areas of need, as well as formulate possible legislative tactics to prevent oversight like this from continuing to occur in such an unequal manner.

Conclusion

This study highlights the urgent need to address water contamination in California, particularly among marginalized communities disproportionately affected by poor water quality. Regional disparities in contamination sources, such as nitrate leaching in Northern California and lead exposure from aging infrastructure in Southern California, pose serious health risks for children, infants, and minority populations. Despite existing regulations, enforcement gaps and delayed interventions exacerbate the issue, as seen in cases like the Oakland Unified School District and Los Angeles public housing projects. These findings emphasize the critical role of environmental justice in ensuring equitable access to clean drinking water.

Future efforts should focus on targeted infrastructure improvements, stricter regulatory enforcement, and greater public transparency. Expanding data collection and assessing the impact of climate change on water quality will be essential for developing effective solutions. Future research should also prioritize community-based monitoring initiatives, portable sensor technologies for real-time contamination detection, and longitudinal evaluation of the effectiveness of policy reforms. However, the generalizability of these findings is limited by regional data variability and the underrepresentation of high-risk populations in public datasets. This study contributes to the growing body of evidence supporting the need for environmental justice–focused water safety policies across California. Addressing these disparities requires immediate action to protect vulnerable populations and promote sustainable water safety policies across California.

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