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Article

Access to public parks, drinking fountains, and clean public drinking water in the Bay Area is not driven by income

Eliza Zaroff[1], Anna Holmquist[2]
[1]The Bay School of San Francisco, San Francisco, California, [2]University of California, Berkeley

SUMMARY

Access to green space—an area of grass, trees, or other vegetation set apart for recreational or aesthetic purposes in an urban environment—and clean drinking water can be unequally distributed in urban spaces, which are often associated with income inequality. Little is known about public drinking water and green space inequities in the Bay Area. For our study, we sought to understand how public park access, drinking fountain access, and the quality of public drinking water differ across income brackets in the Bay Area. We hypothesized that there would be a significant positive correlation between income and the number of drinking fountains, the number of parks, and drinking fountain water quality. For each Bay Area sub-region, we analyzed water samples from four drinking fountains from four different ZIP codes, and recorded the number of parks and fountains in relation to income for eight different ZIP codes. On a large scale, water quality, determined by presence of chemical compounds and other contaminants, was generally high, and there was no significant relationship between income and fountain access, and income and fountain water quality. Though we observed smaller-scale instances of inequalities, in the park distribution in the Bay Area as a whole, and in the Southern Bay's water quality and park distribution, our results indicate that other factors could be influencing water quality, and park and fountain access in the Bay Area.

INTRODUCTION

Environmental injustice, residential segregation, and gentrification are issues that affect access to green space and clean drinking water in the United States. Across 10 metropolitan areas—New York, Los Angeles, Chicago, Houston, Seattle, Phoenix, Indianapolis, Jacksonville, Portland, and St. Louis—income and higher education were found to be positively and significantly associated with access to green space (1). Although nationwide studies on drinking fountain access have yet to be conducted, researchers say fountains are fading from the United States' parks, schools, and stadiums largely due to public mistrust and fear of contamination resulting in poor water quality (2). Breaches in drinking fountain water quality are not uncommon; in 2016, several public water fountains in Chicago were closed down after 445 out of the city's 1,891 water fountains tested positive for lead at levels over the Environmental Protection Agency (EPA)'s action level, which is 15 parts per billion (3). A report published in 2018 found that in 12 states—those with available data on the lead content found in schools' drinking water—12% of all water samples tested had a lead concentration at or above the state's action level (4). In California, while 2% of community water systems receive drinking water that does not meet all primary drinking water standards, 8% of small community water systems (i.e., those serving fewer than 200 connections—about 600 people) violate one or more health-based drinking water standards, and many of these are in communities where the median household income is less than 80% of the state median (5). This evidence points to significant relationships between income and green space, as well as between income and clean drinking water access, which could have implications in a large urban sprawl such as the Bay Area.

To better understand how public park and clean drinking water access differed across the Bay Area, we investigated the accessibility of parks and drinking fountains and the water quality of the latter in each sub-region of the Bay Area. We put an environmental justice lens on the question that guided our research: how do public park access, drinking fountain access, and the quality of public drinking water differ across income brackets in the Bay Area? We hypothesized that there is a positive correlation between median household income and the number of drinking fountains, the number of parks, and the quality of drinking fountain water. Data from the study indicated that on a large scale, while there was no correlation observed between income and drinking fountain water quality, and income and drinking fountain access, there was a correlation observed between income and park access. On a sub-regional scale, we observed a few possible inequities in the South Bay's water quality and park system.

Results

We examined the relationship between median household income and park access, drinking fountain access, and water quality of drinking fountains by testing four water fountains from four different ZIP code areas in five Bay Area sub-regions, resulting in a total of 20 water fountains sampled. Additionally, we counted the number of parks and fountains per square mile and the number of parks and fountains per

	Subregion	TDS (ppm)	Conductivity (µs/cm)	Bromate (mg/L)	Iron (mg/L)	Copper (mg/L)	Lead (PPB)	Nitrite (mg/L)	Nitrate (mg/L)	Chloride (mg/L)	Total Chlorine (mg/L)	Fluoride (mg/L)	Chromium/CR (VI) (mg/L)	Total Alkalinity (mg/L)	pH (mg/L)	Cyanuric Acid (mg/L)
Control		19	34	0	0	0.05	0	0	0	0	0	0	0	0	6.5	30-50
Mountainview	Peninsula	207	440	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
San Bruno	Peninsula	62	131	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Menlo Park	Peninsula	15	31	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Redwood City	Peninsula	14	29	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Los Altos	South Bay	207	440	0	0	0.05	0	0	0	0	0	0	0	40	7	30-50
Cupertino	South Bay	157	334	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
San Jose	South Bay	363	772	0	0	0.05	0	0	0	300	0	0	0	120	7.5	100
Campbell	South Bay	202	429	0	0	0.05	0	0	0	0	0	0	0	80	7	100
Corte Madera	Marin	77	163	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Mill Valley	Marin	76	164	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Larkspur	Marin	89	189	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
San Anselmo	Marin	86	182	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
San Francisco (Presidio Heights)	San Francisco	24	51	0	0	0.05	0	0	0	0	0	0	0	0	6.5	30-50
San Francisco (Pacific Heights)	San Francisco	26	55	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
San Francisco (Glen Park)	San Francisco	18	38	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
San Francisco (Hayes Valley)	San Francisco	25	53	0	0	0.05	0	0	0	0	0	0	0	0	6.5	30-50
Oakland (Grand Lake)	East Bay	36	76	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Berkeley	East Bay	37	77	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Alameda	East Bay	30	63	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50
Oakland (Lakeside)	East Bay	43	91	0	0	0.05	0	0	0	0	0	0	0	0	7	30-50

Table 1: Raw Water Quality Measurements. Control is San Francisco tap water filtered by Franke Filtration Faucet. Color indicates income bracket; red indicates a 2018 median annual household income less than \$65,000, yellow indicates a 2018 median annual household income between \$65,000 and \$115,000 and green indicates a 2018 median household annual income greater than \$115,000.

10,000 people for eight ZIP code areas per sub-region.

We tested water for total dissolved solids (TDS), electrical conductivity (EC), bromate, iron, copper, lead, nitrite, nitrate, ammonium chloride, total chlorine, fluoride, chromium/CR(VI), total alkalinity, pH, and cyanuric acid levels. No measured substance levels exceeded any drinking water standard limits, the majority of measurements were identical across locations (Table 1), and there were no significant differences when compared to the control measurement, San Francisco Tap water filtered by Franke Filtration Faucet. Measurements differed in TDS (86.3 ± 91.0 ppm), EC (194.5 ± 182.2 µs/cm), cyanuric acid (45.7 ± 18.0 mg/L), total alkalinity (31.4 ± 11.4 mg/L), and ammonium chloride levels (65.5 ± 14.3 mg/L). Differences in cyanuric acid, total alkalinity, and ammonium chloride were driven solely by outlier value (Figure 1). Because of this, we disqualified cyanuric acid, total alkalinity, and ammonium chloride levels as appropriate dependent variables to income. TDS and EC had no relationship with median household income (R2 values: 0.005, 0.006, p-values: 0.760, 0.755). Only three ZIP codes—in Los Altos, Campbell, and San Jose—had alkalinity levels above 0. San Jose and Campbell samples also exhibited higher levels (100 mg/L) of cyanuric acid compared to the rest of the samples, which all had between 30-50 mg/L. San Jose had a high concentration (300 mg/L) of ammonium chloride, compared to all other ZIP code locations, which contained none (Table 1). We performed a single factor ANOVA and grouped the data by geographic region to find that there was a significant difference in cyanuric acid ($p = 0.05$) and alkalinity ($p = 0.007$) between groups, and there was not a significant difference in ammonium chloride ($p = 0.438$). Using a Tukey-Kramer test, we found the South Bay to be significantly different from all other groups for alkalinity (adjusted p-value = 0.022). This relationship was not strong for cyanuric acid (adjusted p-value = 0.094). San Jose, Campbell, and Los Altos were all locations where significantly different levels of alkalinity were exhibited; all three receive their water from the San Jose Water Company (11).

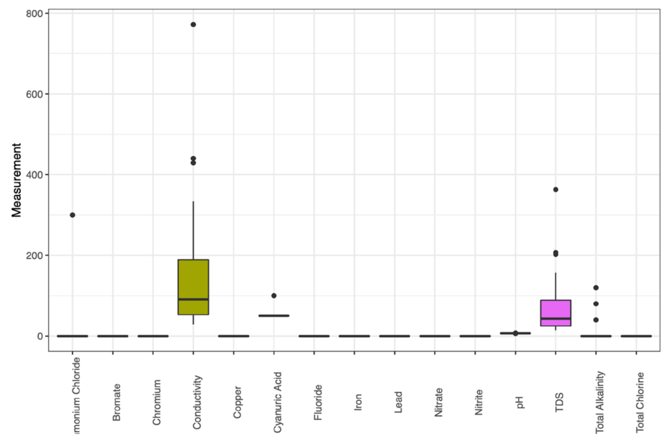

Figure 1: Box plot including values for all water quality metrics. Ammonium chloride, conductivity, cyanuric acid, TDS, pH and total alkalinity showed variability while all other measures returned the same value across samples.

To explore whether a correlation existed between median household income and park and drinking fountain accessibility, we examined eight ZIP codes in each sub-region. We also analyzed four of these for drinking fountain water quality. There was no significant relationship between the averaged values of three of the four variables (fountains per 10,000 people, parks per square mile, and parks per 10,000 people) and averaged income, encompassing all sub-regions (R^2 values: 0.046, 0.219, 0.24, p-values: 0.728, 0.426, 0.402) (Table 2). However, there appeared to be a significant negative correlation between the averaged values of fountains per square mile and averaged income (R^2 value: 0.825, p-value: 0.033) (Table 2). Using the total dataset—as opposed to the 25 averaged values used above—we found that there was a significant positive correlation between ZIP code area income and parks per 10,000 people (R^2 value: 0.115, p-value: 0.032) but there was no significant correlation between income and fountains per 10,000 people in the Bay

Area ZIP codes selected (R^2 value: 0.041, p-value: 0.208) (Figure 2, Table 2). Additionally, there was a significant negative relationship between income and parks per square mile (R^2 value: 0.112, p-value: 0.035) and no significant relationship between income and fountains per square mile (R^2 value: 0.055, p-values: 0.147) (Figure 3, Table 2). On a sub-region scale, in the South Bay, there was a strong positive correlation between income and parks per 10,000 people, while at the same time, there also was a strong negative correlation between income and parks per square mile (R^2 values: 0.712, 0.801, p-values: 0.008, 0.003) (Figure 4, Table 2). There were no significant correlations between income and parks/fountains per square mile and parks/fountains per 10,000 people in Marin, the East Bay, the Peninsula, and San Francisco (Table 2).

DISCUSSION

The water quality component of the study indicated that the water quality of all the drinking fountains measured across the Bay Area was generally high and substance levels met all regulatory standards. Further, water quality was designated as independent of income in the Bay Area (Table 1). This result contrasted several nationwide studies (that show results for the US as a whole) that have demonstrated that low-income and minority communities are disproportionately exposed to poor quality drinking water (12). The lack of positive association between income and water quality in the Bay Area drinking water sampled from fountains indicated that residents usually have access to high-quality drinking water, no matter their income level. The presence of contaminants in water can lead to adverse health effects, including gastrointestinal illness, reproductive problems, and neurological disorders (13). Infants, young children, pregnant women, the elderly, and people whose immune systems are compromised may be especially susceptible to illness from some contaminants (13). It is important to note that our results could have been influenced by our small sample sizes which perhaps kept observed trends from achieving statistical significance. However, taking the results at face value, we can conclude from our data that Bay Area drinking water was generally not posing any significant health risks for residents. This conclusion calls for urban regions containing lower quality water to look into Bay Area water companies' anti-contamination efforts.

	Parks per square mile						
	Combined Data	Averaged Data	San Francisco	South Bay	Marin	East Bay	Peninsula
R^2	0.112	0.219	0.028	0.801	0.063	0.311	0.084
p-value	0.035	0.426	0.69	0.003	0.55	0.151	0.487
F-value	4.777	0.843	0.175	24.123	0.401	2.705	0.549
F-critical	0.035	0.426	0.69	0.003	0.55	0.151	0.487
	Parks per 10,000 people						
	Combined	Averaged	San Francisco	South Bay	Marin	East Bay	Peninsula
R^2	0.115	0.24	0.066	0.712	0.03	0.055	0.268
p-value	0.032	0.402	0.541	0.008	0.684	0.576	0.188
F-value	4.952	0.947	0.421	14.858	0.183	0.349	2.202
F-critical	0.032	0.402	0.541	0.008	0.684	0.576	0.188
	Fountains per square mile						
	Combined	Averaged	San Francisco	South Bay	Marin	East Bay	Peninsula
R^2	0.055	0.825	0.395	0.209	0.002	0.397	0.159
p-value	0.147	0.033	0.095	0.255	0.91	0.094	0.329
F-value	2.196	14.099	3.915	1.585	0.014	3.943	1.131
F-critical	0.147	0.033	0.095	0.255	0.91	0.094	0.329
	Fountains per 10,000 people						
	Combined	Averaged	San Francisco	South Bay	Marin	East Bay	Peninsula
R^2	0.041	0.046	0.44	0.308	0.001	0.245	0.355
p-value	0.208	0.728	0.073	0.153	0.93	0.212	0.119
F-value	1.642	0.145	4.713	2.672	0.008	1.948	3.301
F-critical	0.208	0.728	0.073	0.153	0.93	0.212	0.119

Table 2: Linear regression statistics, using income as predictor and four response variables listed above. Total data and regional data included. The "Combined Data" column contains the linear regression statistics for the complete data set, pictured in Figures 2 and 3. The "Averaged Data" column indicates the linear regression statistics for the average number of parks per square mile, parks per 10,000 people, fountains per square mile, and fountains per 10,000 people for each sub-region vs the average income of each sub-region. The columns named after a sub-region contain the linear regression statistics for the 4 aforementioned variables plotted against the median household income values for the eight examined ZIP codes in each sub-region.

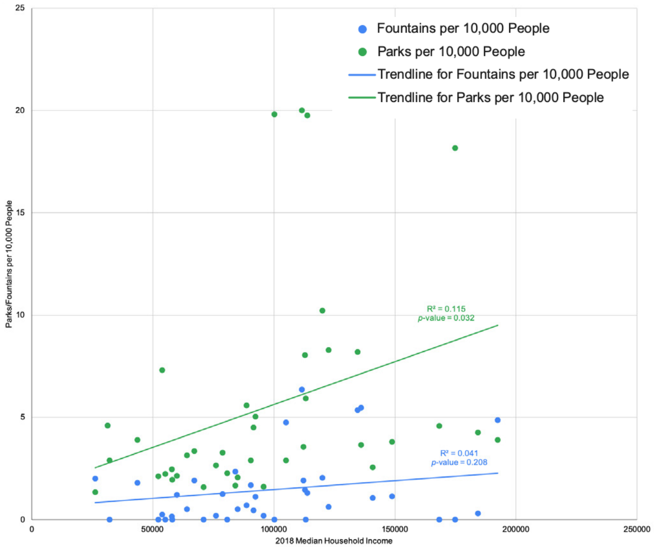

Figure 2: Line of best fit for 2018 Median Household Income vs Fountains per 10,000 People and Parks per 10,000 People.

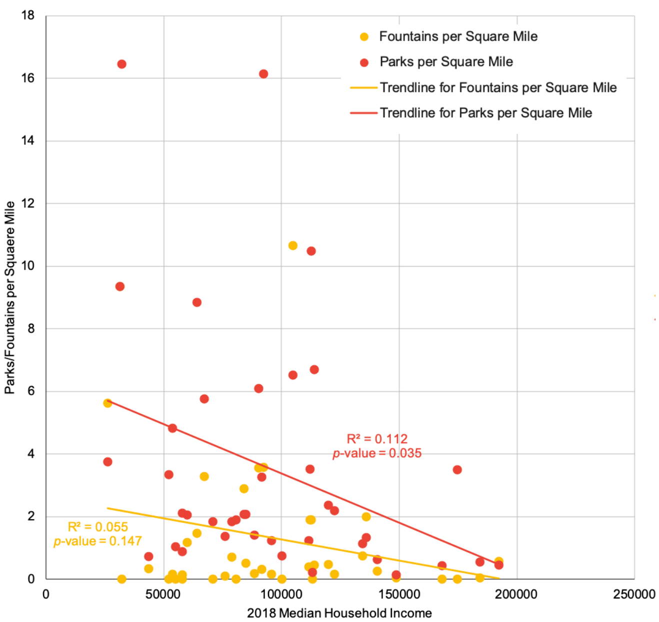

Figure 3: Line of best fit for 2018 Median Household Income vs Fountains per Square Mile and Parks per Square Mile.

The uniformity in the water quality results could be attributed to the limited range of the test strips: there were about 6 possible measurements per contaminant. Additionally, the few places where differences appeared could be attributed to possibly faulty test strips; however, each sample was tested twice and values measured were the same between replicates. The significantly different levels of alkalinity in San Jose, Campbell, and Los Altos ZIP codes call for further research into San Jose Water's infrastructure and water treatment techniques (Figure 1). The San Jose ZIP code that water was sampled from had a 2018 median household income of $37,824—$57,824 below the average

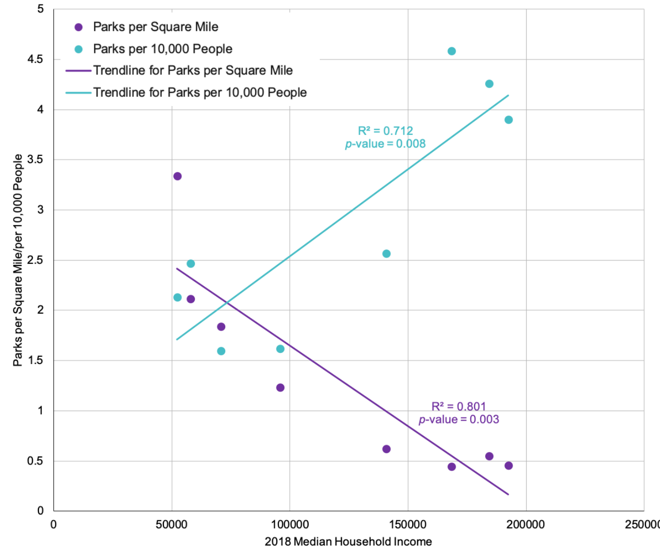

Figure 4: Line of best fit for South Bay 2018 Median Household Income vs Parks per Square Mile and Parks per 10,000 People. The South Bay includes Los Altos, Cupertino, San Jose, and Campbell ZIP codes.

median household income for all analyzed ZIP codes and $12,665 below the median household income for California, suggesting that in some parts of the Bay Area, income can make a difference in water quality (14).

Alkalinity in drinking water is not regulated but is usually between 20 and 200 mg/L. Drinking alkaline water is generally perceived to be safe for the body (15). Cyanuric acid is unregulated in drinking water and is generally used in pools as a chlorine stabilizer, binding to free chlorine and releasing it slowly, extending the time needed to deplete each dose of sanitizer (16). Any amount of cyanuric acid above 90 ppm in pools has been shown to potentially cause sickness if swallowed; the amount found in the San Jose and Campbell fountains was 100 ppm, indicating a potential health hazard (17). Ammonium chloride is a water-soluble salt, primarily used as a component in fertilizers and is also unregulated in drinking water (18). Repeated exposure to ammonium chloride has been found to cause secondary to hyperchloremic metabolic acidosis in laboratory animals, which is characterized by decreased bodyweight, decreased pH in blood and urine, increased serum calcium related to bone demineralization, enlargement of kidney, and adrenal gland hypertrophy (19). At a dose of more than 100 mg/kg of body weight per day, ammonium chloride influences metabolism by shifting the acid-base equilibrium, disturbing the glucose tolerance, and reducing the tissue sensitivity to insulin (20). For the average American male, weighing 88.8 kg, consuming 888 mg of ammonium chloride in one day would predispose him to health issues. This equates to about 3 liters of water from the selected San Jose drinking fountain, which is potentially dangerous since health experts recommend about 2 liters of water per day. Further research needs to be conducted on the health effects of cyanuric acid and ammonium chloride in drinking water to determine whether the EPA should regulate these substances in drinking water, as well as investigation into San Jose Water's anti-contamination efforts.

For the drinking fountain and park access component of the study, there was no significant relationship between income and fountain access on a large scale, encompassing all 5 sub-regions (Figure 2, Figure 3). While there appeared to be a significant negative correlation between the averaged values of fountains per square mile and averaged income values, this could be attributed to the fact that there were only five data points, due to the five sub-regions, in each graph comparing the averaged fountains/parks per 10,000 people and fountains/parks per square mile values with the averaged income values (Table 2). The significant positive relationship between ZIP code area income and parks per 10,000 people indicates that as income increases, there are more parks for fewer people. So, lower-income residents have fewer parks for the same number of people. The significant negative relationship between income and parks per square mile could likely be attributed to the fact that the wealthiest people live in more suburban spaces with more sprawl, where parks are more spread out. This would result in fewer parks per square mile because they are more spread out, but overall more parks for the same population. This relationship between income and park access is reflected in several nationwide studies that exhibit inequities in park access (1, 21, 22). We could extrapolate from our results that a Bay Area resident's income does not seem to impact their access to drinking fountains but may impact their access to parks, amenities that greatly contribute to one's health and wellbeing (23, 24).

The small correlation coefficients for income and park access relationships could be attributed to the fact that park area was not taken into account, although larger parks, such as reserves, could generally be split up into multiple smaller green spaces to ensure accuracy. Marin County exhibited a substantially high number of parks per 10,000 people—this is most likely due to the large number of nature reserves scattered throughout the sub-region. The average median household income of the Marin ZIP codes was also $25,092 higher than the average of all selected ZIP codes, suggesting that the generally high incomes of Marin residents could possibly be linked to the great amount of green space. In the South Bay, the significant positive correlation between income and parks per 10,000 people coupled with the significant negative correlation between income and parks per square mile could be explained by variabilities in population density, park size, and income of the selected South Bay ZIP codes (25). In certain wealthier, less densely populated regions of the South Bay, parks may be more widely spread, leading to lower parks per square mile, but the parks could be larger and less crowded, due to an overall lower population density resulting in more parks per 10,000 people. Whereas in low-income, highly populated urban centers, parks may be tightly packed, resulting in more parks per square mile, while being smaller and more crowded, due to a higher population

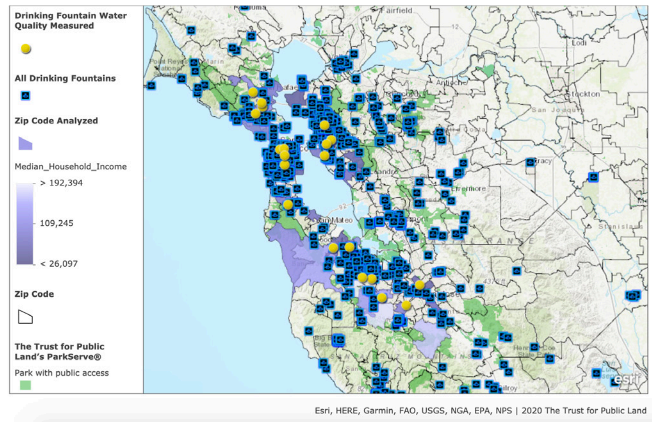

Figure 5: Map of ZIP codes analyzed for drinking fountain and park access, and drinking fountains analyzed for water quality. An interactive map is available: http://bit.ly/2L0UDBM

density. This would result in fewer parks per 10,000 people. This shows a potential inequality in park access in South Bay ZIP codes, as lower-income urban areas seem to not have enough green space for the great number of residents, whereas the opposite is true in higher-income suburban areas.

In conclusion, there were no significant relationships between income and drinking fountain access, and income and public drinking water quality on a large scale. This indicates that other factors, apart from income, could be influencing access to clean drinking water and drinking fountains such as geography. However, we observed instances of injustice in the Bay Area's park distribution as a whole, in addition to the South Bay's water quality and park distribution that call for further investigation.

MATERIALS AND METHODS

Water Quality

To test water quality, four drinking fountains were selected from public parks in each of the five main sub-regions of the San Francisco Bay Area including: San Francisco, supplied by the San Francisco Public Utilities Commission, Marin County, supplied by the Marin Municipal Water District, the East Bay, supplied by the East Bay Municipal Utility District, the San Francisco Peninsula, predominantly supplied by San Francisco Public Utilities Commission and supplementary water utilities, and the South Bay, predominantly supplied by the San Jose Water Company. The four water fountains for each sub-region were selected through the WeTap mobile app, by availability (many public parks were closed due to the COVID-19 pandemic), by ZIP code (all fountains are from different ZIP code areas), and by differences in Esri's 2018 household median income estimates, although there were certain sub-regions where income estimates were generally uniform (6). Water fountain sampling locations can be seen in Figure 5.

Water from the drinking fountains was collected in stainless steel water bottles and kept in the refrigerator for four hours, or until the temperature of the water reached around 70 °F; this was measured with HoneForest's Temperature, TDS, and EC meter. Each bottle of water was tested one at a time. From each bottle, four cups of water were emptied into a shallow glass container, which was washed after every sample. The temperature was recorded a second time to ensure it was close to 70 °F, then the TDS and EC levels were measured, all by using the meter described above. To test for bromate, iron, copper, lead, nitrite, nitrate, ammonium chloride, total chlorine, fluoride, chromium/CR(VI), total alkalinity, pH, and cyanuric acid levels, Test Lab's Drinking Water Test Strips were used. Instructions from the Test Lab's test strips were followed, involving dipping a strip into the water container for two to three seconds before placing it on a paper towel to dry for one minute. Then, the resulting colors were matched with their corresponding substance amounts on the bottle. Note: the colors depicted on the strips were for a range of measurements, meaning that the recorded values are estimates. This process was repeated twice per water sample, involving two strips each time; values were identical between replicates. More information on the test strips can be found here. Additionally, the control—San Francisco Tap water filtered by Franke Filtration Faucet—was tested. The control was chosen to be this because San Francisco is known for having some of the highest quality water, and with the addition of an effective filter, we believed that the sample would be of the highest quality and a reasonable standard for drinking water. In Table 1, MCLG indicates Maximum Contaminant Level Goal, MCL indicates Maximum Contaminant Level, MRDL indicates Maximum Residual Disinfectant Level, and MRDLG indicates Maximum Residual Disinfectant Level Goal.

To determine if there was a correlation between income level and water quality, charts were constructed through Microsoft Excel, an online spreadsheet database. Each substance that was measured, via the strips and meter, was plotted against the median household incomes of the 20 ZIP code areas where the fountains were located. The income values were obtained using Esri's "2018 Popular Demographics" layer (6). To test whether the cyanuric acid, total alkalinity, and ammonium chloride (all the substances that registered different levels between all locations) levels were significantly different when grouped by sub-region, single-factor ANOVA tests were performed. Next, a Tukey-Kramer test was performed for groups found to have a significant variance.

Park and Drinking Fountain Access

For the park and drinking fountain access component of the study, four more ZIP code areas—in addition to the four that were already chosen for water sampling—were selected for each sub-region through ArcGIS. Each sub-region, therefore, had eight total ZIP code areas analyzed for drinking fountain and park numbers; four had drinking water quality data, and four did not. For sub-regions with less income variability (principally San Francisco, Marin, and the Peninsula) the four additional ZIP code areas were chosen randomly, and for sub-regions with more income variability (the East Bay and South Bay), the ZIP code areas were chosen to represent the varying incomes of the sub-region. The data informing the selection of ZIP code areas was Esri's feature layer, "2018 Popular Demographics in the United States", where 2018 median household income values were used. When the ZIP codes were being selected, only Esri's Population Demographics layer was taken into account—the park and fountain layers were not, in order to avoid bias. To collect the number of drinking fountains per ZIP code area, a layer with the coordinates of the 20 fountains that were accessed for water quality and a layer containing water fountain locations from OpenStreetMap database (last updated in 2016), were overlaid on top of Stanford's Census ZIP Code Tabulation Areas shapefile (7, 8). From there, the number of drinking water fountains per selected ZIP code was recorded.

To obtain the number of parks per ZIP code, the same Esri demographic layer was combined with The Trust for Public Land's ParkServe® layer—which includes location for all open-access parks in the US—and the number of public parks per ZIP code area was recorded (9). To calculate the number of parks and fountains per square mile for each ZIP code area analyzed, the recorded numbers of parks and fountains were divided by the water and land area for each ZIP code (10). To measure park and fountain access in relation to population, the numbers of parks and fountains were divided by the 2018 total population for each ZIP code. The quotient was then multiplied by 10,000 to obtain the number of parks and fountains per 10,000 people.

Scatter plots in Microsoft Excel were created. The number of fountains per 10,000 people, the number of parks per 10,000 people, the number of fountains per square mile, and the number of parks per square mile were plotted against the median household income. Four graphs encompassed all 40 ZIP codes analyzed, and 20 were created by sub-region—four graphs for each of the five sub-regions, with each sub-region composed of eight ZIP codes. To test if these relationships were significant, and to obtain the p-values, F-values, and F-critical values, Linear Regression tests were performed for each variable (number of parks per square mile, parks per 10,000 people, fountains per square mile, and fountains per 10,000 people) that was plotted against income (Table 2).

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