A Quantitative Analysis of the Water Quality of Major Water Bottling Brands, Tap Water, and Surface Water in Ocean County, N.J.

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Approximately one in nine people lack access to improved water sanitation and over 3.4 people die each year from poor water sanitation. Therefore, water must be monitored to limit human casualties. While there are annual water quality reports issued by the Environmental Protection Agency, those reports are limited to municipal water quality and do not reflect overall drinking water quality. This study aims to elucidate the water quality of drinking water (tap water and bottled water) in Ocean County, N.J. Water samples from the Barnegat Bay, N.J. and the Atlantic Ocean were also obtained to compare against drinking water. Water quality was evaluated on the presence of these contaminants: nitrates, sulfates, phosphates, chloride, bromide, iodine, copper, and bacteria. Contamination levels were determined using colorimetry to test inorganic ions and ColiscanEasygel® to test bacteria count. Results suggest that higher concentrations of disinfectants in tap water lead to lower colonies of bacteria. Overall water quality is ranked in order of decreasing water quality: Poland Spring®, Aquafina®, Deer Park®, Dasani®, Lakewood, Jackson, Toms River, Berkeley, Manahawkin, Lacey, Ocean water, Brick, and Barnegat Bay.

Key Words: water quality, bottle water, surface water, Ocean County, EPA, USGS, tap water

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Introduction

Throughout history, clean water has proven to be an essential part of life. The human body is comprised of 70% water. Water provides a substrate for red blood cells and hemoglobin to travel. Without hemoglobin to provide the human body with the necessary oxygen, muscle and nerve systems would not function; the human body would shut down. This is why people feel light-headed and nausea following dehydration. Cells require water to transport nutrients and waste and to reproduce. Without water cells would not survive. Essentially, without water life would not exist [1, 3, 6, 13, 20-22]. However, most of the water on Earth is contaminated with either chemicals and/or bacterial.

Water quality has drawn much interest from the business industry, scientific community, and the public over the past few years. Studies conducted by researchers like Burney et al. and Mernild et al. demonstrated a direct correlation between global climate change and adverse side effects like increased sea levels [4, 12]. These studies have sparked the public's interest in water conservation. Many organizations like EPA, water.org, and The Thirst Project have committed themselves to conserve water [9, 20-21]. Now, more than ever, the public is concerned about their drinking water and is interested in preserving the health of water bodies world-wide.

The Environmental Protection Agency (EPA) and the United States Geological Service (USGS) provide the public with many data, maps, and resources regarding the water quality of specific regions (Figure 1). However, these data are regionalized and do not provide specific data values but ranges of contamination levels. For example, figure 1 depicts nitrates, chloride, and TDS in 2012. Note that specific data values are not provided and that trends and patterns are provided only for large regions of the United States (Figure 1). Local areas like Chicago, IL; Orange Park, FL; and Brick, NJ cannot obtain specific contamination levels regarding their local drinking water [9, 20]. Thus, this study aims to alleviate this issue and create specific data values for contamination levels in

drinking water and surface water for Ocean County, NJ. All previous studies on water quality were conducted on a large, regionalized area. Never has such an in-depth study on water quality been so focused and centralized on one county in the United States. Thus, the purpose of this study is to not only provide local residents with information regarding their drinking water but also urge EPA and USGS to conduct more focused and specialized water monitoring programs.

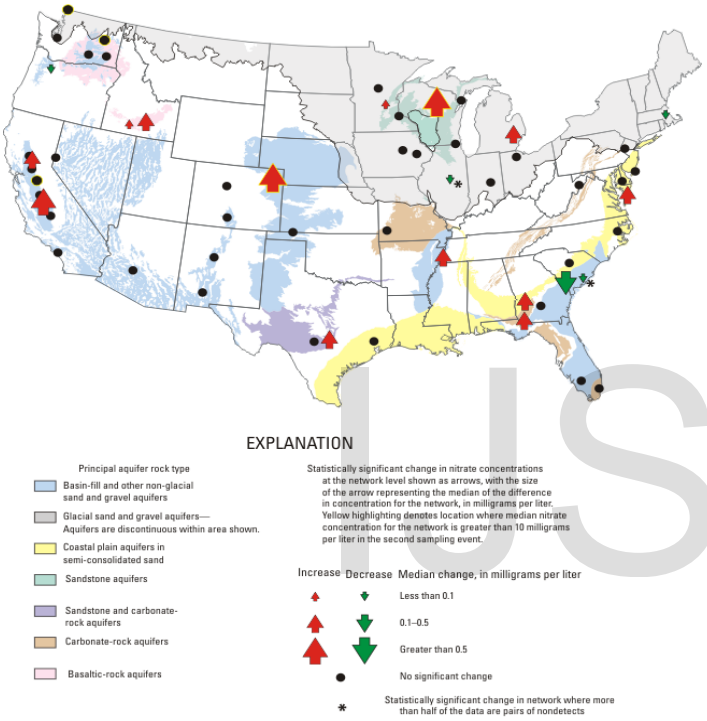

Figure 1: Distribution of nitrates, chlorides, and total dissolved solids in groundwater in the contiguous United States in 2012

In addition, studies before were mainly focused on municipal, ground, and surface water and never ventured into bottled water [1, 3, 4, 10-18,]. Bottled water, while packaged, may still contain levels of contaminants like chlorine and iodine. Corporations like Coca-Cola® and Pepsico® do not release data regarding the minerals or substances in their water. Therefore, this study also aims to give the public a better understanding of the physical composition of their bottled water.

Municipal water (tap water) and bottled water are of primary interest. Major bottling brands like Aquafina®, Dasani®, Deer Park®, and Poland Spring® obtain their water from different sources and employ different purification techniques which results in different contaminants present. Deer Park® and Poland Spring® waters are obtained from a natural spring with preexisting minerals and bacteria [8, 16]. These brands undergo a purification process to remove bacteria but retain the mineral rich taste. Other brands like Aquafina® and Dasani® are purified water, so they obtain their water from a public source and utilizes carbon and reverse osmosis filters to remove impurities [2, 7]. Dasani® also adds substances like potassium chloride and magnesium sulfate to enhance taste. These bottling techniques will result in different soluble substances in the water compared to natural spring water. Municipal water are also of interest as each municipality employs their own purification process that results in different contaminants [15]. Furthermore, the Barnegat Bay Watershed and the Atlantic Ocean are also fascinating to offer comparison between contamination levels in drinkable water and non-potable water.

For this study, water quality is determined upon the following contaminants present sulfate, nitrate, phosphate, iodine, chlorine, bromine, copper, and coliforms (E-coli). These parameters were chosen based on the EPA's Contaminant Candidate List, which lists these eight parameters as common water quality indicators [9]. Nutrients (nitrate, sulfate, and phosphate) are considered a major water threat because they over fertilize the water body and promote excessive algae growth. The abundance of algae will deprive the water system of oxygen and create a dead zone void of life [1-2, 10, 13]. Disinfectants (bromine, iodine, and chlorine) are commonly used by municipalities and bottling companies to remove bacteria in their water. However large amounts of disinfectants are harmful to living organisms, hence their usage.

Iodine irritates the eyes and respiratory system and can lead to death if ingested in high doses. Bromine irritates the eyes and is corrosive to the skin. chlorine attacks the respiratory tract and causes coughing and flu-like symptoms; chlorine in high doses can be fatal. Copper is a metal found in natural ores and is used in household plumbing. Due to how Ocean County drains into the Barnegat Bay, copper leeching is prominent and enters local water bodies and intake sources for many municipalities [9]. Bacteria, specifically e-coli, is also prominent in water sources and can lead to abdominal cramps, bloody diarrhea, and ultimately death [17]. Due to the danger and common occurrence of these eight contaminants, they were selected as the parameters to evaluate water quality.

It should be noted that this study was conducted from the fall of 2011 to the spring of 2012, and the results only reflect the water quality from that time frame. Now, water quality may be different; for example, bottling plants and municipalities may have initiated new purification methods that may have decreased contaminants present. Also, other water quality parameters like turbidity, macro-invertebrates count, and volatile organic compounds were not measured as a mean to determine water quality. Thus, this study is limited by the parameters measured.

In total, this study has a three-fold hypothesis. Bottled water are made for commercial sale. Thus to ensure high consumer ratings and maximum revenue, bottled water undergo intense purification like reverse osmosis (Dasani®). Typically, the water produced should be clean and of excellent quality [1, 7-8, 16]. **Therefore, it is hypothesized** that bottled water would have some of the best water quality compared to the other water samples based on the parameters measured. Surface water like the ocean and the bay are natural water sources and do not undergo any artificial purification. In fact, many organisms like Quahogs (*Mercenaria mercenaria*) and Red Beard Sponge (*Microciona prolifera*) thrive on a turbid, high-nutrient aquatic environment to filter feed and grow [1]. **Thus, it is hypothesized** that surface water would have some of the worst water quality of the samples. Of all the municipalities, Brick houses one of the most sophisticated water monitoring and water purifications systems in New Jersey: ion chromatography, colorimetry, sediment settling tanks, salinity sensors, disinfectant tanks, and much more. Brick MUA maintains a close watch on their intake sources: Metedeconk River and insures that their tap water are of high quality with little bacterial contamination. Like many commercial bottling plants, Brick MUA enhances their water with minerals to preserve their tap water and elimination bacterial growth after treatment. **Thus, it was hypothesized** that Brick tap water would have high water quality compared to the others.

Methodology

Study Site

The Barnegat Bay watershed is one of the biggest watersheds in New Jersey. It is comprised of 33 municipalities in Ocean County, N.J. and 4 municipalities in Monmouth County, N.J. It is home to over 500,000 residents and a plethora of animals and plants. Rivers like the Metedeconk River (Brick MUA intake source) and Toms River feeds into this watershed. In total, around 21,000 acres of the Barnegat Bay watershed is reserve as a wildlife refuge [23]. This makes the Barnegat Bay watershed one of the largest in New Jersey.

Procedures

Aquafina®, Dasani®, Deer Park®, and Poland Spring® were the 4 bottled water sources. Bottled water were purchased from Shop Rite™, local super market in Ocean County, N.J. [14]. Berkeley, Brick, Jackson, Lacey, Lakewood, Manahawkin, and Toms River were the 7 towns

with 7 different municipalities where water was gathered. The samples were gathered from consistent residential homes over the study period. Barnegat Bay and Atlantic Ocean were the 2 surface water sources. Distilled water was also tested as the control because DI water contains only the pure H_2O molecules and nothing else [1]. In other words, DI water was the control and bottled water, municipal water, and surface water were the controls to be tested. In total, water samples were gathered from 14 different sources: Aquafina®, Barnegat Bay, Berkeley, Brick, Dasani®, Deer Park®, Distilled Water, Jackson, Lacey, Lakewood, Manahawkin, Atlantic Ocean, Poland Spring®, and Toms River.

Figure 2: Image of some of the water samples gathered.

Water samples were gathered on November, 20, 2011; December, 20, 2011; January, 20, 2012; February, 20, 2012. This created a total of 56 samples, n=56, (14 sources x 4 samples each = 56 samples).

After 45 minutes upon collection, the water samples were tested for inorganics via the LaMotte® SMART 2 Colorimeter. The LaMotte® SMART 2 Colorimeter was calibrate and samples were ran following operator's instructions for each test [19]. Each test was evaluated 4 times per each of the sampling dates and water sources, totaling 56 trials per contamination E-coli bacteria count was determined via a total ColiscanEasy Gel® solution, Petri dishes, pipettes, and an incubator. Upon pouring the water sample (individually) into the Petri dish, they were combined with 10 mL of the Coliscan® solution and left to solidify in an incubator for 24 hours. The coliform test was carried out with 10 mL of the water samples. In order to compensate how bacteriological readings are expressed in colonies per 100 mL of water, results were multiplied by 10. This was conducted 4 times each for each of the 14 samples, totaling 56 trials. Overall, 392 trials were conducted for the 7 parameters.

Next, a simple ranking system was devised to rank the sources for water quality. Depending on the amount of contamination present, each of the fourteen water samples were ranked in order from one to fourteen. The source with the highest contamination levels was given a grade of 14, while the source with the least contamination was given a grade of 1. This ranking system was applied to each individual parameter and once more for overall water quality. The numerical grades were added together and the source with the lowest number was the cleanest and vice versa.

Statistical Analysis

Data collected were analyzed using SPSS statistical software: t-test pair two samples for mean and ANOVA with an alpha value of 0.05 or less used for significance between data sets. Statistical difference means that the data did not occur by chance and are good representations of the actual data.

Figure 3: Image of the LaMotte colorimeter

Figure 4: Colorimeter and reagent testing setup. and reagents used for contamination detection.

On May 7, 2013, nine water tests were performed and macro-invertebrates were gathered at Oxycccus Bog. Dissolved oxygen was measured via a Winkler titration involving the LaMotte Dissolved oxygen Test Kit 5860®. An Extech thermometer was used to determine the temperature needed to calculate the percent saturation of the dissolved oxygen. A sample was placed in a drawer and after five days the sample was retested for dissolved oxygen, which was the BOD test. Fecal coliform counts were measured with LaMotte BioPaddles 5540®. The pH was measured with API pH Test Kit 28®. Nitrates were measured with API Nitrate Test Kit LR1800® and Phosphates were measured with API Phosphate Test Kit 63L®. Total solids were tested by filtering 500 mL of sample water through a Corning Incorporated 500 mL Filter (Figure 2). The mass left on the filter paper was then weighted for suspended solids. A 25 mL sample was taken after the filter and evaporated to obtain dissolved solids (Figure 3). Turbidity was measured with an Oakton Turbidimeter T-100®.

Macro-invertebrates were gathered with a combination of D-frames (Figure 4) and kick-screens. This constitutes the natural method to gather macros. Three natural leaf packs were also created and placed in the water for five days to mimic an artificial habitat to lure macros. All the macros gathered were counted and sorted according to their order.

Results

The p-values were all determined to be less than 0.05. This meant that the contamination readings were significantly different from each other; thus, they could be compared to each other to accurately display the town's contamination level differences.

Nitrate readings in the 14 samples ranged from 7.25 ppm to 11.5 ppm with Jackson tap water with the lowest level and Toms River with the highest level. In general, bottled water tend to have lower nitrate levels compared to municipal treated water.

Chlorine readings ranged from a low of 0.0375 ppm for ocean water to a high of 0.285 ppm for Aquafina®. Five percent standard error bars indicate that there are not distinct differences among chlorine levels in the water samples (figure 6). For example, Poland Spring has relatively low chlorine levels, but Aquafina has exceptionally high chlorine.

Iodine levels ranged from 0.1325 ppm to 2.5875 ppm. Lowest readings were observed for Dasani®, while highest readings were observed Lacey tap water. Error bars and trends suggest that municipalities tended to have higher iodine levels. Bottled water and surface water tended to have lower iodine levels (figure 8).

Phosphate levels ranged from 0.0325 ppm in Toms River tap to 0.335 in Berkeley tap. Error bars and trends indicated that bottled water tend to have lower phosphate levels, while surface water had higher levels (figure 9). There was no visible correlation among phosphate levels in municipalities.

Sulfate levels ranged from 3.5 ppm in Poland Spring® to 20.025 ppm in the Barnegat Bay. Trends indicated that surface waters tended to have high levels of sulfate followed by municipal water followed by bottled water (Figure 11).

Copper levels spanned from 0.005 in Lakewood tap water to 0.3525 in the Barnegat Bay.

Trends indicated that copper levels were low in all sources except the two surface water sources. Manahawkin also had high copper levels (0.14 ppm). It should be noted that the sampling home for Manahawkin tap water was an older home that utilized many copper-based plumbing (figure 13). This may have contributed to copper leeching and high readings.

Bromine levels ranged from 0.1025 ppm for Dasani® to 1.76 ppm Lacey tap water. Graph indicate that municipalities like Lacey and Brick tended to have high bromine levels, while bottled water were low in bromine (figure 14). Barnegat bay also had moderate high levels of bromine.

E-coli readings deviated from 32.5 colonies/100 mL of water to 322.5 colones/100 mL of water. High bacterial colonies were noted in surface water. Moderate bacteria colonies were observed in both municipal water and bottled water. In general, Lacey, Toms River, and Brick recorded low bacteria colonies (figure 15). Highest bacteria count was recorded for the ocean and lowest bacteria colonies were recorded for Brick tap water.

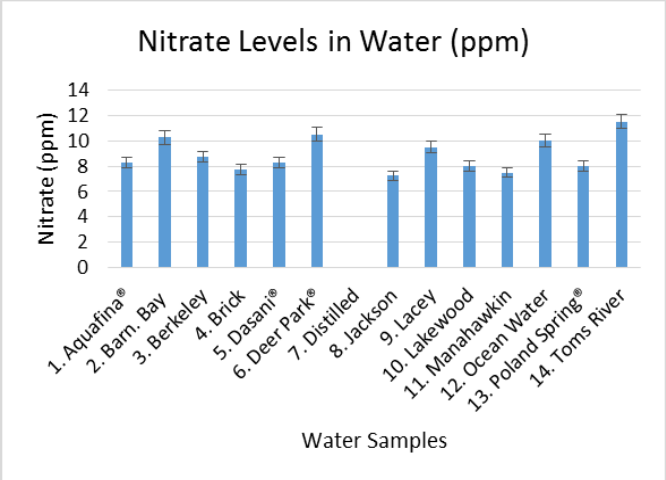

Figure 5: Graphical depiction of nitrate levels with +/-5% standard deviation

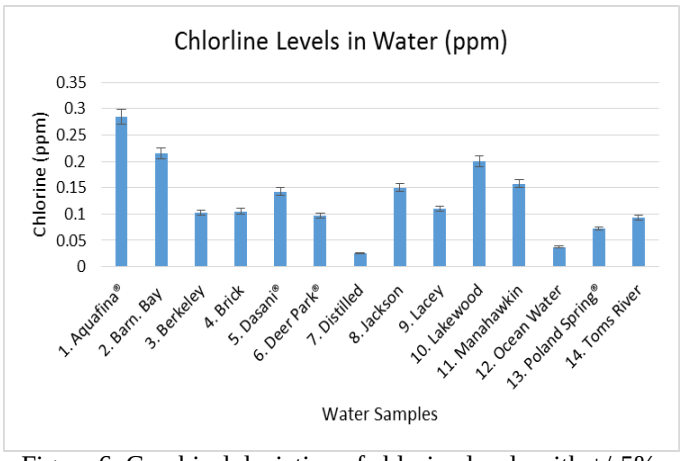

Figure 6: Graphical depiction of chlorine levels with +/-5% standard deviation

Figure 7: Photo of five of the Chlorine test vials. Note that the darker the pink hue, the greater the chlorine level

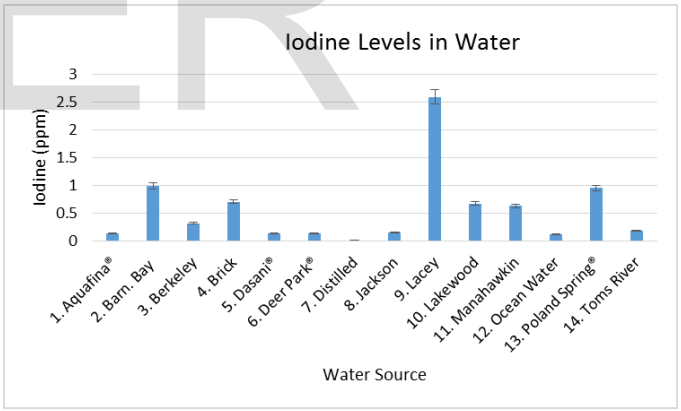

Figure 8: Graphical depiction of iodine levels with +/-5% standard deviation

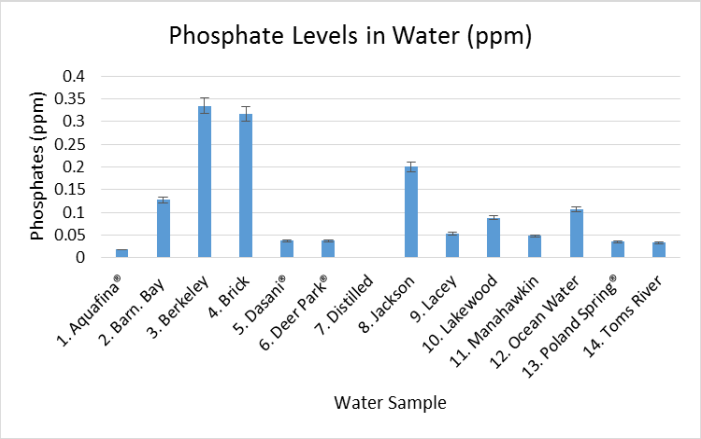

Figure 9: Graphical depiction of phosphate levels with +/-5% standard deviation

Figure 10: Photo of five of the Phosphate test vials. Note that the darker the blue hue, the greater the phosphate levels

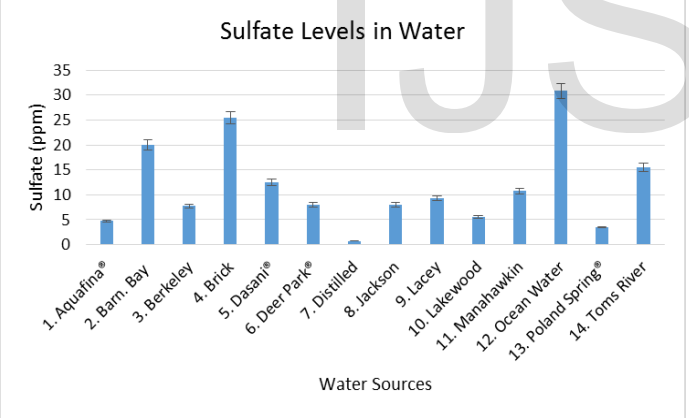

Figure 11: Graphical depiction of sulfate levels with +/-5% standard deviation

Figure 12: Photo of five of the Sulfate test vials. Note that the darker the white hue, the greater the sulfate concentration.

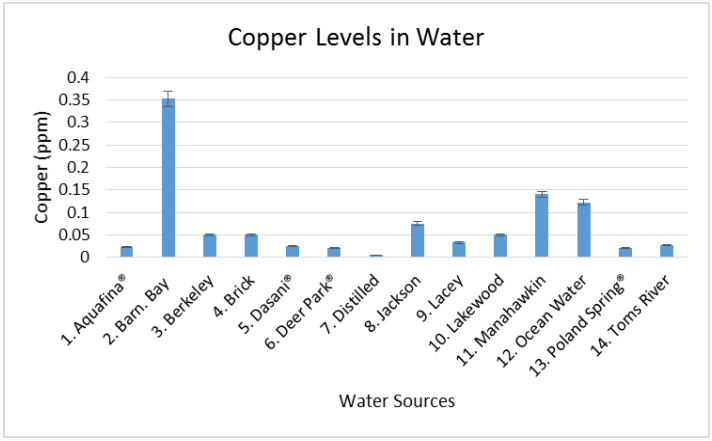

Figure 13: Graphical depiction of copper levels with +/-5% standard deviation

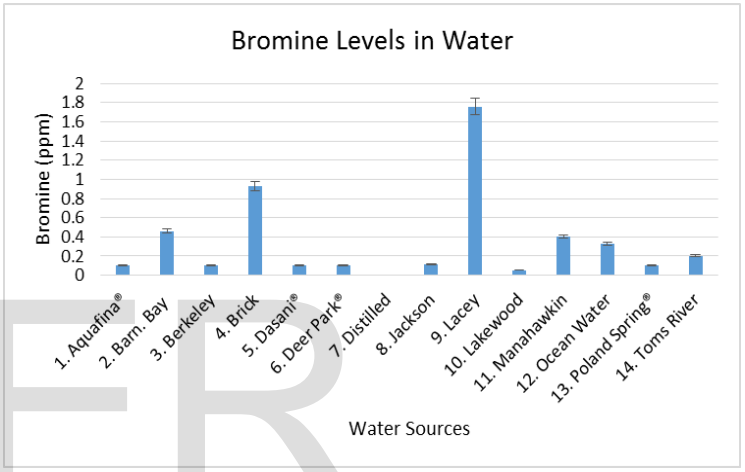

Figure 14: Graphical depiction of bromine levels with +/-5% standard deviation

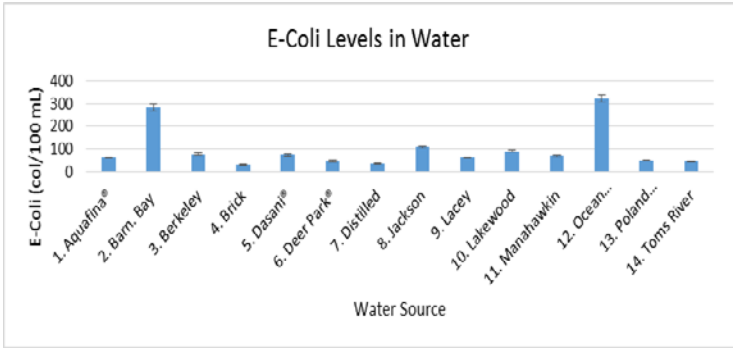

Figure 15: Graphical depiction of E-coli levels with +/-5% standard deviation

Overall water quality based on the eight parameters tested indicated that Poland Spring® ranked at the top with 37 points and Barnegat Bay water ranked last with 97 points. Excluding surface water and solely focused on drinking water indicated that Brick ranked last with 73 points.

Water quality of the samples are ranked as follows in order of increasing contamination: Poland Spring®, Aquafina®, Deer Park®, Dasani®, Lakewood, Jackson, Toms River, Berkeley, Manahawkin, Lacey, Ocean water, Brick, and Barnegat Bay (Table 1). Once again, these results only indicate the water quality based on the eight parameters measured during the sampling time frame and do not reflect water quality today.

Table 1: Point system ranking. Distilled ranked as "0" as it was the control. Poland Spring® bottled water ranked at the top, while untreated Barnegat Bay water ranked last (which helped to support my ranking system).

Samples	Chlorine	Iodine	Bromine	Sulfate	Copper	Nitrate	Phosphate	Bacteria	Total	Ranking
1. Aquafina	10	4	4	4	6	8	3	7	46	2
2. Barn. Bay Water	9	13	12	13	14	12	11	13	97	13
3. Berkeley	8	8	8	6	10	9	14	10	73	8
4. Brick	14	9	13	12	10	6	13	1	78	12
5. Dasani	5	3	5	10	7	8	6	9	53	4
6. Deer Park	4	5	7	7	5	13	6	4	51	3
7. Distilled	1	1	2	2	4	3	2	2	17	0
8. Jackson	6	6	8	7	11	4	12	12	66	6
9. Lacey	13	14	14	8	9	10	8	7	83	10
10. Lakewood	7	7	3	5	10	7	9	11	59	5
11. Manahawkin	12	11	11	9	13	5	7	8	76	9
12. Ocean Water	3	10	10	14	12	11	10	14	84	11
13. Poland Spring	2	2	7	3	5	7	5	6	37	1
14. Toms River	11	12	9	11	8	14	4	3	72	7

Figure 16: Image of Metedeconk River.

Discussion

The results of this study gives residents in Ocean County, N.J. a better understanding of the water quality of their drinking water. Instead of qualitative date from EPA, USGS, and their local municipalities like good, fair, and danger, this study gives residents empirical, quantitative data about their drinking water. At the same time, this study gives organizations like EPA and USGS a glimpse into the effects of providing empirical data to smaller, focused regions instead of providing ranges of numbers to large regions. This type of study that is smaller and more focused allows for more accurate readings and does not let other areas interfere with the data. For example, the Barnegat Bay is associated with the Delaware River in the same region [23]. However, if the Delaware River has low water quality when the Bay has excellent water quality, then the readings will not accurately represent the Bay. The two water bodies are in different regions and should have their own set of readings and should not be regionalized at that level.

Hypothesis one and two on how bottled water had the best water quality and how surface water had the worst water quality, respectively, proved to be true based on figure 5-15. In fact, bottled water garnered the top 4 spots on the water quality ranking system. Surface water had the worst water quality as they are natural occurring water systems that do not undergo any kind of purification. Nutrient runoff is prominent in Ocean County as many residents near by the bay and the ocean [23]. Thus, nutrient levels are especially high in the bay and the ocean. Likewise, many bacteria thrive in the water so bacterial colonies were extremely high for both the bay and the ocean. An interesting note is that high disinfectant levels were discovered in the bay and the ocean. This due to how there are waste water plants in Ocean County that collect used water and treat it with disinfectants and then release the treated water out to the bay, which then leaks into the ocean [9]. This method of recycling water prevents high accumulations of algae and other contaminants into the bay and the ocean. This is why disinfectants were found in surface water. The third hypothesis was not proven to be true. In fact, Brick tap water was ranked near the bottom for water quality. This does not meant that Brick tap water is necessary harmful for human consumption. Rather it means that based on the

parameters tested, Brick tap is not the best water source. From a data standpoint, Brick tap has poor water quality; however, in reality, Brick water is excellent. Granted this trend is only observed for Brick tap. The ranking system was based on the amount of contaminants present and the lower the amount equates to a better water quality. However, it neglects to state that high levels of disinfectants may equate to lower amounts of bacterial growth. Brick ranks 14, 9, and 13 in chlorine, iodine, and bromine concentrations. Yet, Brick ranks number 1 in bacterial growth. This demonstrates that high levels of disinfectants lead to lower bacterial growth. This stipulation to the ranking system is only observed for Brick tap as they use high levels of disinfectants and do not apply to the other water sources.

Spring water has naturally occurring levels of nitrate, sulfate, phosphate, and iodine minerals that are not removed during purification. This led to high levels of these parameters during testing. However, brands like Aquafina® and Dasani® purify their water via disinfectants and adds minerals like magnesium sulfate to enhance the taste [2, 7, 8, 16]. This resulted in high chlorine levels for Aquafina® and high sulfate levels for Dasani®. Many municipalities use disinfectants to remove bacteria and this is clearly reflected during testing. Overall, this study depicts a good representation of the water quality of the surface water, tap water, and bottled water in Ocean County, N.J. The fact that readings were gathered over a span of 5 months depict a nice representation of the overall water quality.

A future study would involve testing the same samples for post-Sandy impact. As this study was conducted a few months before Hurricane Sandy, these results provide pre-Sandy data on water quality that could be compared to post-Sandy studies. This will enable people to determine the effects of a tropical storm on the water quality of Ocean County. Likewise, this study could be incorporated into a long term water quality monitoring program that can span a few years to accurately depict water quality. This study also has industry implications. These data provide the water quality in 2011-2012. Businesses and firms can use the results of this study as a base line to improve their water purification methods. For example, reliance could be lessen on disinfectants as a mean to remove bacteria and use other methods like decreasing pH to remove bacteria. As per the parameters studied, this method would increase the water quality of the sample. This study was not intended to sway consumers to purchase or drink one type of water in lieu of another. Rather this study informs the public of their drinking water, and consumers should know that different types of water have their own pros and cons: purified water may be high in disinfectants when spring water may be high in minerals.

Conclusion

EPA, USGS, and municipalities do not provide empirical data regarding the water quality of drinking water and surface water. Likewise, little has been done to quantify the water quality of bottled water. This study attempts to elucidate this issue and provide the public with water quality data on tap water, surface water, and bottled water in Ocean County, N.J based on the concentration of these parameters: chlorine, iodine, bromine, nitrate, sulfate, phosphate, copper, and e-coli. Results suggest that water quality of the samples are ranked from high to low water quality: Poland Spring®, Aquafina®, Deer Park®, Dasani®, Lakewood, Jackson, Toms River, Berkeley, Manahawkin, Lacey, Ocean water, Brick, and Barnegat Bay. The hypotheses that bottled water and surface water would have the best and worst water quality respectively was proven. The hypothesis that Brick tap water was high in water quality was rejected. Furthermore, this study is a pre-Sandy analysis and could be used in conjunction with post-Sandy

studies to determine the effects of Hurricane Sandy on water quality.

Resources

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