All-in-One Filter Device for Removing Contaminants from Water in Hydraulic Fracturing Communities

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Research Paper Authors
Alisha Bhatia, Corresponding Author
alishabhatia432@gmail.com
(408) 620-0167
Merit Academy
Po Box 2988
Santa Cruz, CA 95063

Mark W. Oleksak, Research Lead
STEM Pioneers Group, Inc.
Boca Raton, Florida, USA

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ABSTRACT

There are approximately 1 million hydraulic fracturing wells in the United States, producing over 20 billion barrels of wastewater each year. Chemicals from these wells contaminate the groundwater, cause environmental damage, and harm human health. This project aims to develop a low-cost, all-in-one personal filter device that removes volatile organic compounds (VOCs), heavy metals, and bacteria at EPA standards. The prototype was designed to provide an effective water flow, mitigate pressure issues, and remove color, taste, and smell. A pump sprayer with activated carbon (AC), an ethylenediaminetetraacetic acid (EDTA) resin, and a 0.2 µm filter were used for the prototype. The VOCs and bacteria levels were represented by total organic compounds (TOC) and chemical oxygen demand (COD) levels. Heavy metals were tested separately. The results demonstrated that AC removes VOCs and the 0.2 µm filter removes bacteria, as TOC was decreased by a range of 69.8-92.2% and COD was decreased by a range of 83.8-94.8%. The results also indicated that EDTA removed aluminum by 91.3%, copper by 66.6%, lead by 100.0%, and zinc by 100.0%. This study can lead to the application of an individual filter for families in fracking areas as an improved line of defense against contaminated water.

INTRODUCTION

Over 20 billion barrels of wastewater are produced each year in the United States due to hydraulic fracturing. Hydraulic fracturing, or fracking, is a process where high-pressure fluid is injected into rock formations to obtain oil and natural gas [1]. To increase fluid pressure, over 1100 compounds are added, including volatile organic compounds (VOCs), heavy metals, inorganic compounds, and radioactive elements [2]. Additionally, microbial growth can occur in the wastewater, as bacteria thrive on hydrocarbons [3].

Hydraulic fracturing poses a serious threat to Earth's ecosystems and the environment. Methane is released during fracking, which is 34 to 86 times as potent of a greenhouse gas as carbon dioxide [4]. Fracking chemicals can contaminate groundwater through well leakage (**Fig. 1**) [5] and underground fractures that enable them to travel up to the water aquifer [6]. Wastewater is also often managed in harmful ways. One management strategy is storing wastewater in evaporation ponds, where carcinogens from fracking fluid can evaporate into the atmosphere [6]. Another common method is injecting wastewater back into the aquifer, polluting organisms' supply of clean water [7]. While some companies treat wastewater using reverse osmosis before releasing it, small solutes with low molecular weight are likely to remain [7].

Chemicals in the water aquifer cause deleterious health complications in humans [8]. The National Toxics Network (NTN) in Australia analyzed 362 hydraulic fracturing chemicals using material safety data sheet (MSDS) information, scientific literature, and government reports [7]. According to the NTN, 55% of such chemicals impair the brain and nervous system, 22-47% cause long-term health issues like cancer, and 78% damage skin, liver, eyes, and other sensory organs [7]. One study conducted by the Johns Hopkins School of Public Health found that people living near fracking areas were 1.5 to 4.4 times as likely to develop asthma [9]. Another Johns Hopkins study found that women living near fracking sites in Pennsylvania had a 40% increased chance of delivering a premature baby and a 30% increased chance of having a high-risk pregnancy [10]. Researchers in West Virginia found that pregnancy issues can be attributed to endocrine-disrupting chemicals near the fracking sites (Kassotis et al., 2016) [11].

The goal of this study is to manufacture a personal filtration device to supplement municipal water treatment, providing further protection against health complications from contaminated water. Numerous water filtration methods fail to remove all key contaminant groups and only remove some specific combinations of VOCs, heavy metals, microorganisms, and sediment (CDC, 2020) [12]. Some commercial filters remove key contaminants, though these filters are often quite expensive. This proposed all-in-one device using activated carbon (AC), ethylenediaminetetraacetic acid (EDTA), and a 0.2 μm filter will be designed to adequately remove hydraulic fracturing chemicals. Previous research establishes that AC removes VOCs [13, 14], EDTA removes heavy metals [15], and 0.2 μm filters remove sediment and bacteria [16].

MATERIALS AND METHODS

Materials Listing

See **Table 1**.

Materials Preparation

A working portable filter with AC, an EDTA resin, and a 0.2 μm filter was developed after nine prototype phases. Each material required preparation before use. To mitigate AC particulates from leaching into the filtered water, 75.0 grams of AC was soaked in 125 mL of water and refrigerated for seven days. After the third day, 12.5 mL of household (3% purity) hydrogen peroxide was added to the AC and water mixture. Refrigeration and hydrogen peroxide were used to reduce bacterial growth in the water [17-19]. After washing and refrigeration, the AC was placed in the container (see **Fig. 2**).

An EDTA resin was used to eliminate heavy metals, involving a multi-step preparation process. The EDTA resin was prepared from Invitrogen™ ProBond™ Ni-NTA resin in a 2.6 cm by 1.9 cm column. The resin consisted of a plastic material with covalently-attached EDTA moieties. Initially charged with nickel ions bound to EDTA moieties, a 0.2 M Tetrasodium EDTA solution was injected through the column. The consistent flow of EDTA solution caused the nickel to unbind from the resin and rebind to the 0.2 M EDTA solution. Once the nickel was removed, the EDTA moieties were available to bind new metals. The EDTA resin was also rinsed with water until the conductivity of the filtered water matched the conductivity of tap water, 0.550 mS. When the conductivities matched, the EDTA ions from the solution were no longer being leached into the filtered water [20]. After the EDTA resin was thoroughly rinsed, the resin was attached to the pump sprayer (see **Fig. 2**).

For bacterial removal, a 0.2 μm filter was placed on the water intake tube and on the exit nozzle (see **Fig. 2**). A plastic spacer was first placed on the tube and nozzle. A 0.2 μm filter was placed on the plastic spacer, and another plastic spacer was placed on top to secure the 0.2 μm filter. Teflon tape was used to secure each material. The layering of plastic spacers was performed to ensure that the 0.2 μm filter would not fracture from the abrasive AC or outside environment. The three main filter components were now available for testing.

Working Prototype Preparation

The prototype was constructed with a Vivosun 0.2 Gallon Pump Sprayer, ensuring that adequate pressure was applied on the water to pass through the EDTA resin and 0.2 μm filter. The AC was placed inside the main container (g) and 0.2 μm filters were secured in two locations (f, k). Fastening the EDTA resin cartridge to the pump sprayer required multiple steps. Teflon tape was applied to the nozzle of the resin cartridge (t) to form a base for the plastic tube (l). A zip tie (s) was attached to secure the seal. The other end of the plastic tube was attached to a plastic fitting on the pump sprayer. With the AC, 0.2 μm filters, and EDTA resin secured, set-up of the prototype was complete.

Adding the EDTA resin required further adjustments to the prototype. Due to resin's compact nature, additional pressure was necessary to propel water out the filter. Additionally, air leaked out the top hole (q). To increase air pressure, teflon tape was wrapped around the plunger handle rod (r) connecting to the lid, creating a barrier so that air cannot escape. Holding down the lever (n) while pumping the plunger (m) enabled a continuous stream of filtered water. Wrapping teflon tape (p) around the top of the pressure generator (e) also increased pressure, inhibiting the release of air through the gap between the generator (e) and lid (o). Once the air pressure issues were resolved, water flowed through the prototype successfully.

To assess the water flow in **Fig. 2**, the unfiltered water was first placed inside the container by removing the lid of the pump sprayer (a). The water came in contact with the AC on the bottom (g) to remove any dyes and VOCs. Pressing down on both the plunger handle (m) and sprayer lever (n), the water enters the bottom of the plastic tube (b) and travels upwards (h) to the connecting lid (o). The 0.2 μm filter was connected to the bottom of the tube (f) to prevent the uptake of AC particulates. Once the water traveled through the tube, it was propelled (c) through the EDTA resin (i) to remove heavy metals. Finally, the water exited through another 0.2 μm filter (k) on the resin nozzle to filter bacteria and particulates (d).

Water Sample Collection

Experimental samples were collected from sites in Texas and California. In 2021, Texas contained the most fracking wells and was the leading producer of wastewater nationwide [21]. In **Fig. 3** [22], fracking wells were indicated by the green circles.

Three samples were collected from Corpus Christi, Texas. Unfiltered and filtered water were acquired from the Corpus Christi Water Department. The nearest fracking well was located around 8 miles from the water department (**Fig. 4**) [22]. Natural gas pipelines, indicated by the purple lines, were present throughout the city. Filtered water from the department was treated through conventional water treatment, which removed bacteria, viruses, and parasites; chloramines eliminated harmful biological activity. Additionally, coagulation and flocculation removed key heavy metals and VOCs. Aluminum sulfate was added to the water, and metals bound to the positive charge of aluminum sulfate. This compound settled to the bottom of the basement, forming a sludge that was extracted from the filtered water. Total dissolved solids were not removed. The third sample was collected from a gas station bathroom sink in Corpus Christi located near the water department.

One sample was collected from residential locations in Padre Island, TX. While Padre Island did not have any fracking wells nearby, it contained several natural gas pipelines (**Fig. 5**) [22]. Another sample was collected from Cupertino, CA, surrounded by two natural gas pipelines (**Fig. 6**) [22]. Both served as moderately clean samples.

Water Samples

See **Table 2**.

Water Testing Materials

The three pollutant categories of interest were VOCs, microorganisms, and heavy metals. The Envig Digital Water Quality Sensor measured total organic compounds (TOC), chemical oxygen demand (COD), and total dissolved solids (TDS) (**Table 3**). While TOC measured carbon levels in organic compounds, COD measured oxygen consumed by oxidizable compounds, typically organic and some inorganic compounds [23, 24]. Together, TOC and COD indicated the level of microorganisms, VOCs, pesticides, and inorganic chemicals; TDS designated the total amount of inorganic salt [25]. The Safe Home Heavy Metals Test Kit measured key heavy metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, sodium, and zinc [26]. The samples were tested with US EPA Method 200.7, using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES).

Water Testing Procedures

VOCs and bacteria from unfiltered samples were measured with the Envig sensor. Samples of 45 mL were collected from each of these locations: tap water from Cupertino for the control, tap water from Padre Island, filtered water from the Corpus Christi Water Department, water from a Corpus Christi gas station bathroom sink, and unfiltered water from the water department. Before testing, the Envig sensor was calibrated using deionized water, ensuring that TDS, TOC, and COD were set to 0.0 ppm. Each trial was taken by pressing the sensor button, as the contamination level for each category was displayed. Six trials were taken per sample.

VOCs and bacteria were then measured for the samples filtered by the prototype. The AC was washed with 800 mL of tap water before raw water samples were filtered. Starting with tap water from Cupertino, 150 mL was poured inside and filtered. Filtered samples of 20 mL were collected, and six trials were taken using the Envig sensor. The residual water was poured out the filter. Removing the EDTA resin cartridge from the pump sprayer, the filter was rinsed with 1.2 L of tap water and 100 mL deionized water. Using a syringe, 2-3 mL of deionized water was propelled through the EDTA resin cartridge. This process was repeated for each sample. Two series of six trials were conducted to measure consistency.

The Safe Home Heavy Metals Test Kit was used to test heavy metals. Water from the Corpus Christi gas station was used due to its availability and moderately high contamination level. For the unfiltered sample, 120 mL gas station water was collected and placed in a bottle. For the filtered sample, 200 mL gas station water was placed in the filter, and 120 mL filtered gas station water was placed in another bottle. Both samples were shipped to Environmental Laboratories, Inc. in Madison, IN. Results were received eight days after shipment.

RESULTS

VOC and Bacteria Results with Envig Sensor

Results were organized in tables comparing the before and after filtration levels for each sample. Bar graphs visually represented the difference in TDS, TOC, and COD levels; each bar displayed the average value of all trials. TOC and COD were analyzed by taking the mean of the two averages for both trials. Each sample was analyzed in terms of EPA ratings: excellent (<100 ppm for TDS, 0.0-1.0 ppm for TOC and COD), good (100-300 ppm for TDS, 1.0-1.5 ppm for TOC and COD), fair (300-1000 ppm for TDS, 1.5-3.0 ppm for TOC and COD), and poor quality (>1000 ppm for TDS, >3.0 ppm for TOC and COD) [25].

Deionized Water

See **Table 4**.

Tap Water from Cupertino

The contaminant levels were displayed in **Table 5**, organized in graphs (**Fig. 7**), and analyzed. The average TDS level increased from 268 to 330 ppm (23.1%), lowering the EPA rating from good (100-300 ppm) to fair (300-1000 ppm). In contrast, the average TOC and COD level decreased, indicating the removal of pollutants. The TOC level decreased from 2.08 to 1.06 ppm (49.0%), raising the EPA rating from fair (1.5-3.0 ppm) to good (1.0-1.5 ppm). The COD level decreased from 1.55 to 0.49 ppm (68.4%), improving the EPA rating from fair (1.5-3.0 ppm) to excellent (0.0-1.0 ppm).

Tap Water from Padre Island

The contaminant levels were displayed in **Table 6**, organized in graphs (**Fig. 8)**, and analyzed. The average TDS level decreased from 299 to 197 ppm (34.1%); while the TDS level decreased, the EPA rating remained a good quality (100-300 ppm). The average TOC level decreased from 2.55 to 0.77 ppm (69.8%), raising the EPA rating from fair (1.5-3.0 ppm) to excellent (0.0-1.0 ppm). The average COD level decreased from 2.28 to 0.37 ppm (83.8%), raising the EPA rating from fair (1.5-3.0 ppm) to excellent (0.0-1.0 ppm).

Filtered Water from Corpus Christi Water Department

The contaminant levels were displayed in **Table 7**, organized in graphs (**Fig. 9**), and analyzed. The average TDS level decreased from 366 to 202 ppm (44.8%), improving the EPA rating from fair (300-1000 ppm) to good (100-300 ppm). The average TOC level decreased from 3.93 to 0.71 ppm (81.9%), raising the EPA rating from poor (>3.0 ppm) to excellent (0.0-1.0 ppm). The average COD level decreased from 3.20 to 0.35 ppm (89.1%), raising the EPA rating from poor (>3.0 ppm) to excellent (0.0-1.0 ppm).

Water from Corpus Christi Gas Station Bathroom Sink

The contaminant levels were displayed in **Table 8**, organized in graphs (**Fig. 10**), and analyzed. The average TDS level decreased from 243 to 217 ppm (10.7%); while the TDS level decreased, the EPA rating remained a good quality (100-300 ppm). The average TOC level decreased from 5.12 to 0.40 ppm (92.2%), raising the EPA rating from poor (>3.0 ppm) to excellent (0.0-1.0 ppm). The average COD level decreased from 3.65 to 0.19 ppm (94.8%), raising the EPA rating from a poor (>3.0 ppm) to excellent (0.0-1.0 ppm).

Unfiltered Water from Corpus Christi Water Department

The contaminant levels were displayed in **Table 9**, organized in graphs (**Fig. 11**), and analyzed. The average TDS level decreased from 380 to 331 ppm (12.9%); while the TDS level decreased, the EPA rating remained a fair quality (300-1000 ppm). The average TOC level decreased from 14.6 to 1.25 ppm

(91.4%), raising the EPA rating from poor (>3.0 ppm) to good (1.0-1.5 ppm). The average COD level decreased from 10.5 to 0.64 ppm (93.9%), raising the EPA rating from poor (>3.0 ppm) to excellent (0.0-1.0 ppm).

Heavy Metal Results with Safe Home Test Kits

Results of the unfiltered and filtered samples from the Corpus Christi gas station water were organized in a comparison table (**Table 10**) showing the before and after filtration heavy metal levels. A graph was also used as a visual representation for the change in aluminum, copper, lead, and zinc levels (**Fig. 12**). The graph was designed this way because the other heavy metals were not detected (ND) in the water. Sodium was also not included in the graph because it was considered a light metal. The levels were also analyzed using EPA limits for each heavy metal: 0.2 ppm for aluminum, 1.0 ppm for copper, 0.015 ppm for lead, and 5.0 ppm for zinc.

The aluminum level decreased from 0.208 to 0.018 ppm (91.3%); while initially above the EPA limit (0.200 ppm), the filter removed a significant amount of aluminum. Though the initial copper, lead, and zinc levels were all below the EPA limit (0.018 < 1.0 ppm for copper, 0.007 < 0.015 ppm for lead, and 0.027 < 5.0 ppm for zinc), the levels were significantly lower after filtration. Copper reduced from 0.018 to 0.006 ppm (66.6%); both lead and zinc were completely filtered out, lead decreasing from 0.007 to 0.000 ppm (100.0%) and zinc decreasing from 0.027 to 0.000 ppm (100.0%).

DISCUSSION

The filter effectively reduced VOCs, bacteria, and heavy metals. In terms of EPA ratings, TOC and COD typically improved from a lower rating to a higher one. Additionally, the experiment was replicable and consistent among several trials, as samples were obtained from a variety of locations near fracking wells and natural gas pipelines.

The filter design was developed as a low-cost and effective model and was constantly modified whenever there were obstructions. Ten filter models were designed over the three-year development process, each addressing the optimal way to remove contaminants and improve water pressure. Commercial AC filters were evaluated first since they were used in most household filter products. While they removed VOCs, they did not remove metals. The commercial AC filter was accordingly modified with 0.1 M EDTA. Two filter versions using AC and EDTA were manufactured: a 5-inch plastic filter column and batch testing with AC clusters coated in EDTA [27]. Magnesium and copper were used as heavy metals for testing. Several filter models also used chitosan, a polymer from shellfish skeletons that removed heavy metals [28]. The final model incorporated an EDTA resin since it maximized heavy metal removal and minimized other unfavorable factors such as color, taste, and smell. A garden pump sprayer was used because it reduced leakage and enabled water to flow through the system.

Nonetheless, the filter design also presented shortcomings that can be improved in future works. While TOC and COD were removed significantly, TDS typically only decreased slightly. The filter's flow rate was also minimal, as one drop of water exited the filter every second. This occurred due to a lack of pressure in the pump sprayer, as air leaked through the top hole. The EDTA resin's compact design also increased the difficulty of water exiting the nozzle. Despite adjustments being implemented, the pressure was only adequate for water to flow through the system.

The experimentation process also had areas of development. As more contaminated water was filtered, more metals bound to the EDTA resin. Therefore, EDTA moieties were less available to bind metals from future water samples. Furthermore, while the prototype was washed with water after each sample, the 0.2 μm filters were not replaced. If the 0.2 μm filters were replaced, more TOC and COD could have been removed. Another drawback was the type of instrumentation. Though the Envig sensor provided strong quantitative data for TOC, COD, and TDS levels, these categories holistically represented microorganisms, VOCs, pesticides, and inorganic chemicals. Due to limited availability of unfiltered water from the Corpus Christi Water Department, the gas station water from the Corpus Christi bathroom sink was used instead for heavy metal testing. While the gas station water was the next most polluted sample, unfiltered water from the water department would have provided more information on the EDTA resin's capacity to remove heavy metals.

Improvements can be applied to the filter design and experimental process for future prototypes. Successive models should maintain a high pressure for faster flow rate. Another consideration is the longevity of filter materials, such as the AC, 0.2 μm filter, and EDTA resin. People can invest in replacement materials, or larger prototypes could be constructed with more material. In the experimental process, water samples can be collected from sites throughout the United States for a more comprehensive report on hydraulic fracturing contamination. If cost is not a limitation, higher lab-grade equipment can be used to identify and analyze contaminants before and after filtration.

CONCLUSIONS

Once adjustments are implemented, this filter can supplement municipal treatment in removing hydraulic fracturing chemicals from drinking water. Organizations can use this product if they have a concern about water quality in fracking sites. An awareness campaign can be established and delivered in conjunction with the availability of this filter device. This may motivate oil and gas industries to become more proactive in providing solutions to fracking well leakage and water contamination.

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I would also like to thank Dr. Mayowa Osundiji for providing in-depth information regarding filter types, environmental and health hazards of chemicals, and overall project design.

The authors report there are no competing interests to declare.

TABLES

Table 1 Materials for each experimental component.

For Prototype	Vivosun(™) 0.2 gallon pump sprayer Plastic tube (5 mm inner rim, 8 mm outer rim) Zip tie Teflon tape
For AC Preparation	AC Household (3% purity) hydrogen peroxide
For EDTA Resin Preparation	Invitrogen™ ProBond™ Ni-NTA (EDTA resin)
For 0.2 μm Filter Preparation	0.2 μm filters Teflon tape Plastic spacers
Water Samples	Unfiltered water from Corpus Christi Water Department Filtered water from Corpus Christi Water Department Water from Corpus Christi gas station Tap water from Padre Island, TX Tap water from Cupertino, CA
For Water Testing	Conductivity meter Measuring scale Envig Digital Water Quality Sensor Safe Home Heavy Metals Test Kit

Table 2 Water samples collected from various locations.

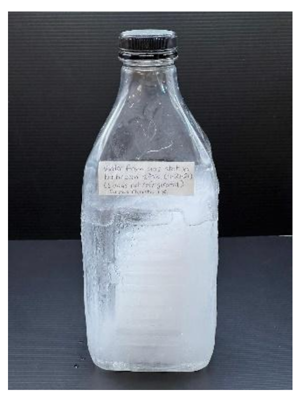
Unfiltered Water from Corpus Christi Water Department	Filtered Water from Corpus Christi Water Department	Water from Corpus Christi Gas Station Bathroom Sink	Tap Water from Padre Island
			

Table 3 Materials for water testing.

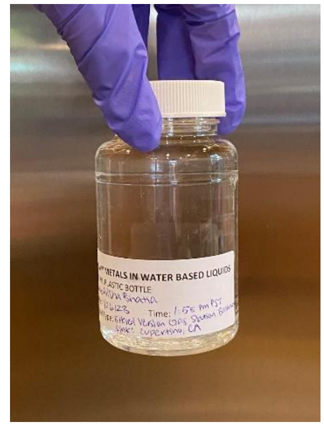
Envig Sensor	Water collected for Safe Home test kits (before and after filtration)	
		

Table 4 Deionized water TDS, TOC, COD levels.

	Deionized Water for Calibration (~45 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOC (ppm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COD (ppm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5 Tap water from Cupertino TDS, TOC, COD levels.

	Tap Water from Cupertino - Before (~45 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	266	270	270	263	270	268	268
TOC (ppm)	2.1	2.1	2.1	2.0	2.1	2.1	2.08
COD (ppm)	1.6	1.6	1.6	1.5	1.5	1.5	1.55

	Tap Water from Cupertino - After (~20 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	335	336	336	334	335	335	335
TOC (ppm)	1.3	0.5	0.9	0.9	1.1	1.0	0.95
COD (ppm)	0.6	0.2	0.4	0.4	0.5	0.4	0.42
TDS (ppm)	324	325	326	324	327	326	325
TOC (ppm)	1.2	1.4	1.4	0.9	1.0	1.1	1.17
COD (ppm)	0.6	0.7	0.7	0.4	0.4	0.5	0.55

Table 6 Tap water from Padre Island TDS, TOC, COD levels.

	Tap Water from Padre Island - Before (~45 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	295	295	299	298	306	302	299
TOC (ppm)	2.5	2.6	2.6	2.6	2.5	2.5	2.55
COD (ppm)	2.3	2.3	2.4	2.3	2.2	2.2	2.28

	Tap Water from Padre Island - After (~20 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	182	181	181	181	181	180	181
TOC (ppm)	1.3	1.3	1.4	1.3	1.3	1.3	1.32
COD (ppm)	0.7	0.7	0.7	0.6	0.6	0.6	0.65
TDS (ppm)	211	214	209	214	214	213	213
TOC (ppm)	0.6	0.2	0.0	0.0	0.0	0.5	0.22
COD (ppm)	0.2	0.1	0.0	0.0	0.0	0.2	0.08

Table 7 Filtered water from Corpus Christi water department TDS, TOC, COD levels.

	Filtered Water from Corpus Christi Water Department - Before (~45 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	343	365	365	369	374	377	366
TOC (ppm)	3.8	4.0	4.2	3.9	3.9	3.8	3.93
COD (ppm)	3.1	3.2	3.3	3.3	3.2	3.1	3.20

	Filtered Water from Corpus Christi Water Department - After (~20 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	205	203	203	203	141	196	192
TOC (ppm)	1.3	1.3	1.3	1.3	1.2	1.2	1.27
COD (ppm)	0.7	0.7	0.7	0.6	0.6	0.6	0.65
TDS (ppm)	211	212	209	209	212	211	211
TOC (ppm)	0.3	0.2	0.0	0.1	0.0	0.3	0.15
COD (ppm)	0.1	0.1	0.0	0.0	0.0	0.1	0.05

Table 8 Water from Corpus Christi gas station bathroom sink TDS, TOC, COD levels.

	Water from Gas Station Bathroom Sink - Before (~45 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	227	238	241	243	250	260	243
TOC (ppm)	4.2	5.1	5.2	6.2	5.0	5.0	5.12
COD (ppm)	3.3	3.6	3.6	4.2	3.6	3.6	3.65

	Water from Gas Station Bathroom Sink - After (~20 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	216	215	218	215	217	217	216
TOC (ppm)	0.1	0.0	0.3	0.5	0.4	0.3	0.27
COD (ppm)	0.3	0.0	0.1	0.2	0.2	0.1	0.15
TDS (ppm)	217	216	217	216	218	218	217
TOC (ppm)	0.8	0.0	0.5	0.5	0.7	0.7	0.53
COD (ppm)	0.3	0.0	0.2	0.2	0.3	0.3	0.22

Table 9 Unfiltered water from Corpus Christi water department TDS, TOC, COD levels.

	Unfiltered Water from Corpus Christi Water Department - Before (~45 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	366	375	379	382	388	389	380
TOC (ppm)	15.1	16.0	14.8	14.2	13.8	13.7	14.6
COD (ppm)	10.3	10.8	10.6	11.1	9.8	10.6	10.5

	Unfiltered Water from Corpus Christi Water Department - After (~20 mL)						
Parameter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average
TDS (ppm)	324	322	320	196	320	322	301
TOC (ppm)	1.3	1.6	1.3	1.3	1.3	1.3	1.35
COD (ppm)	0.7	0.9	0.7	0.7	0.7	0.7	0.73
TDS (ppm)	359	360	360	361	361	357	360
TOC (ppm)	1.4	1.3	1.0	1.3	0.9	1.0	1.15
COD (ppm)	0.7	0.6	0.5	0.7	0.4	0.4	0.55

Table 10 Comparison for before and after filtration heavy metal levels for water from Corpus Christi gas station bathroom sink.

	Heavy Metals Comparison	
	Before	After
Aluminum (ppm)	0.208	0.018
Arsenic (ppm)	ND	ND
Cadmium (ppm)	ND	ND
Chromium (ppm)	ND	ND
Copper (ppm)	0.018	0.006
Iron (ppm)	ND	ND
Lead (ppm)	0.007	0.000
Manganese (ppm)	ND	ND
Sodium (ppm)	104	61.600
Zinc (ppm)	0.027	0.000

FIGURES

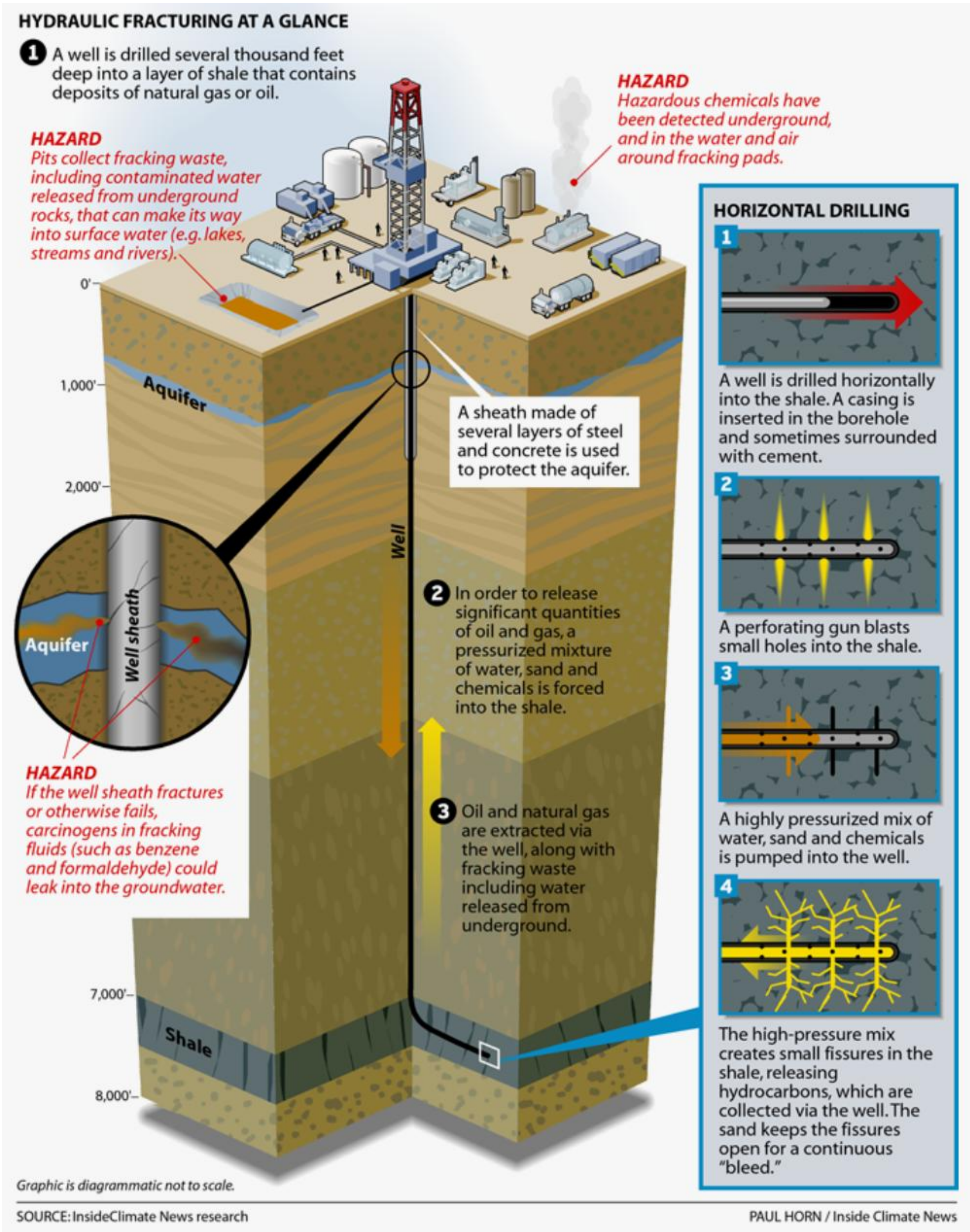


Fig. 1 Well leakage leading to water contamination (Berwyn, 2021).

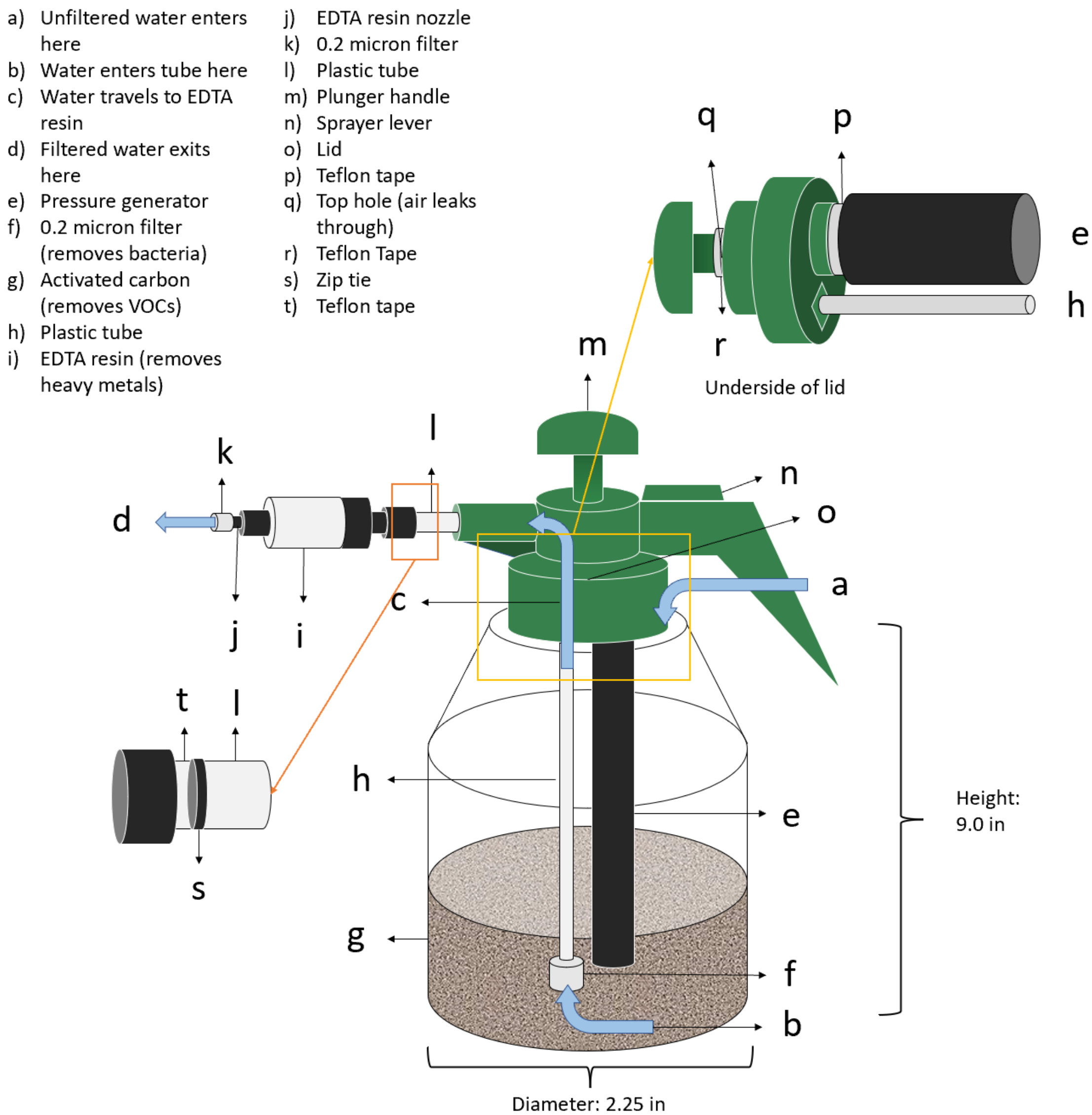


Fig. 2 Prototype for water filter.

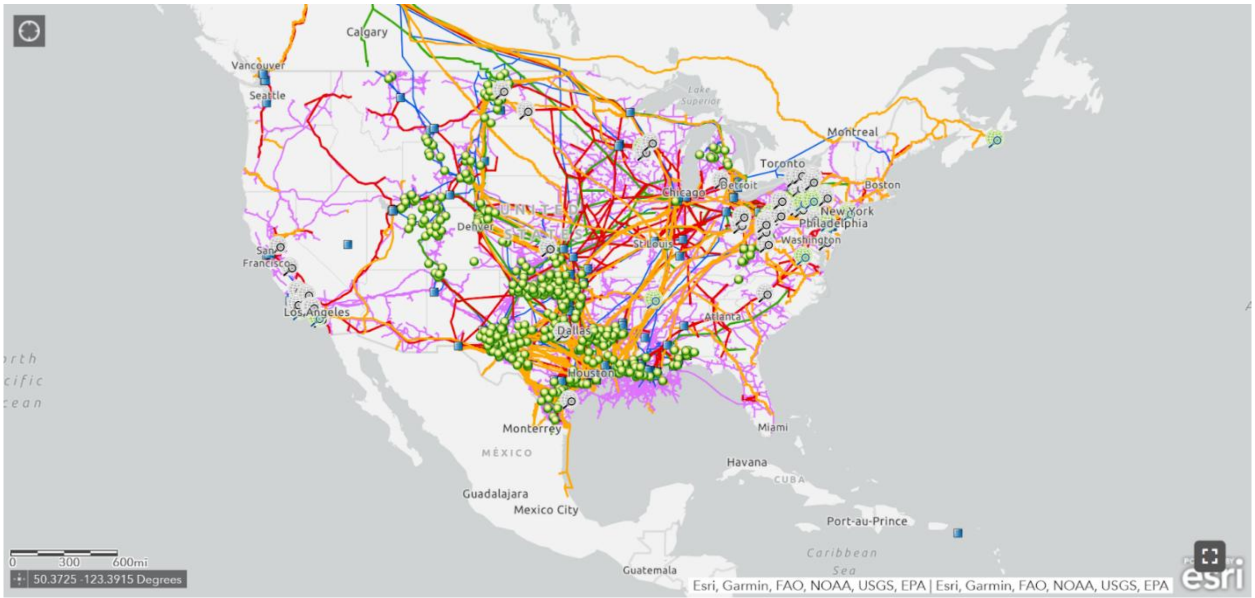


Fig. 3 Hydraulic fracturing processing plants throughout the United States (National Energy and Petrochemical Map, 2021).

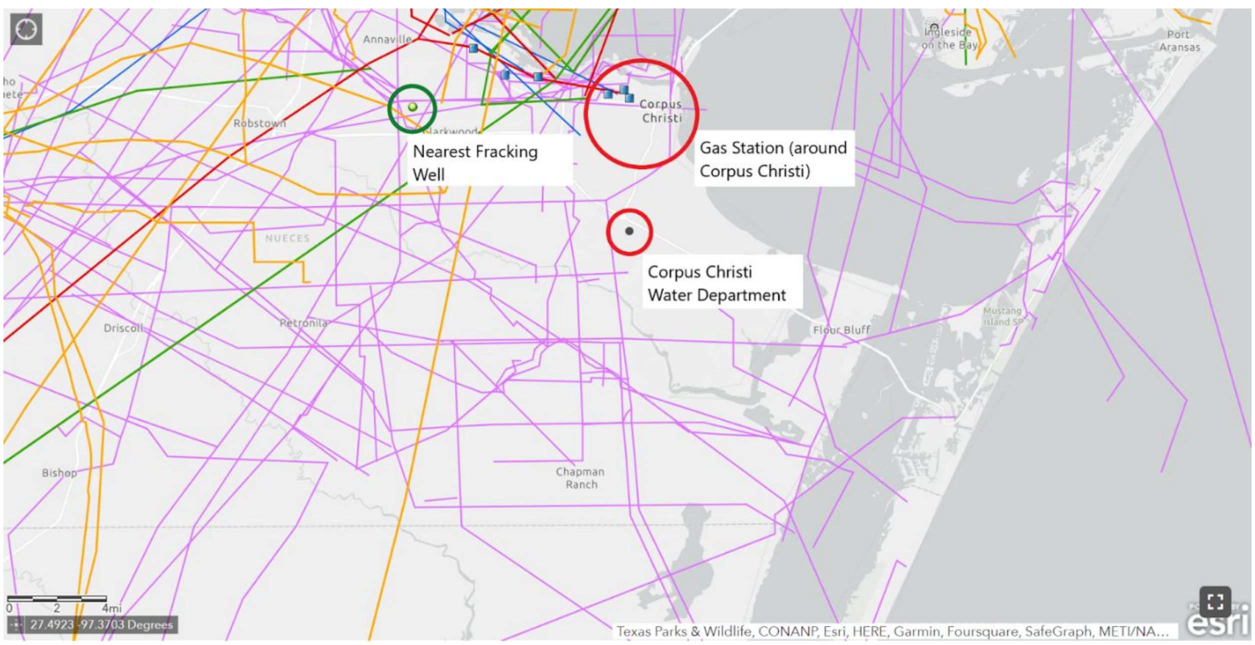


Fig. 4 Hydraulic fracturing processing plants near Corpus Christi, TX (National Energy and Petrochemical Map, 2021).

Fig. 5 Tap water sample location near Padre Island, TX (National Energy and Petrochemical Map, 2021).

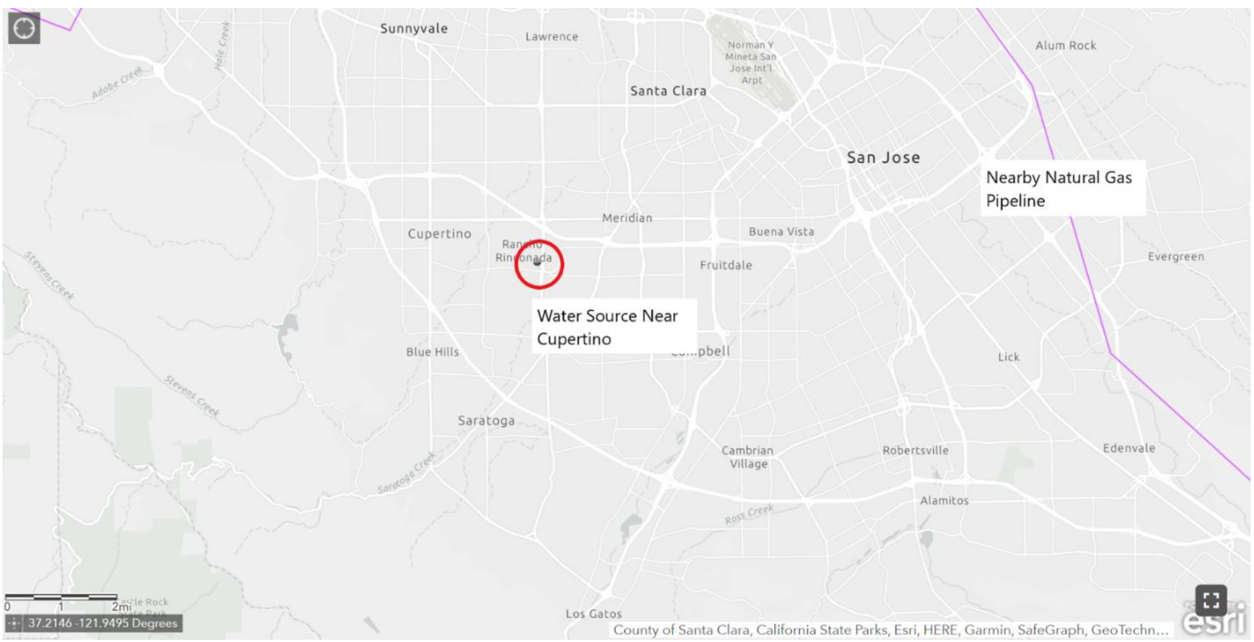


Fig. 6 Tap water sample location near Cupertino, CA (National Energy and Petrochemical Map, 2021).

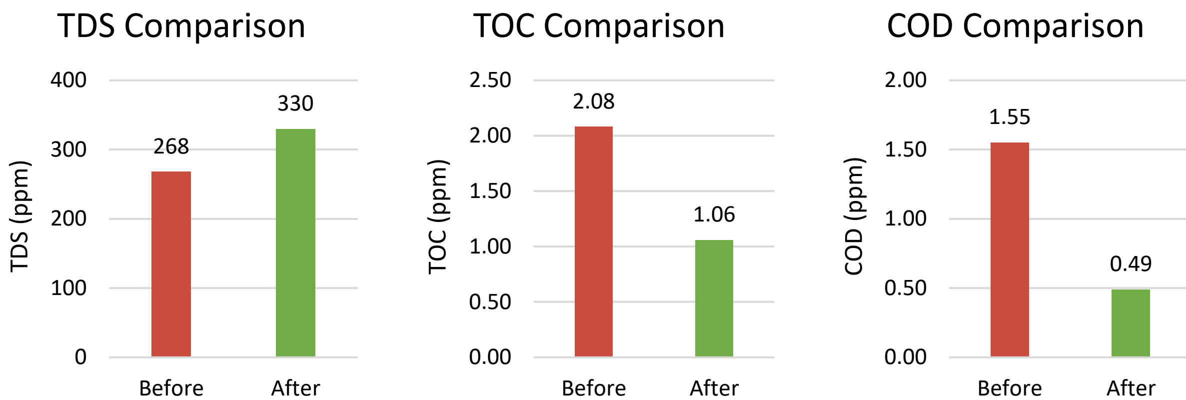


Fig. 7 Tap water from Cupertino before and after comparison.

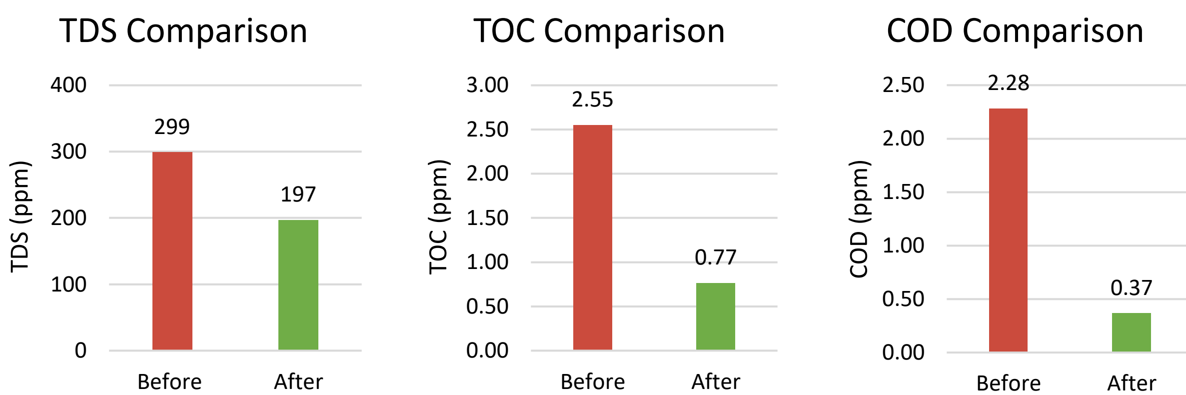


Fig. 8 Tap water from Padre Island before and after comparison.

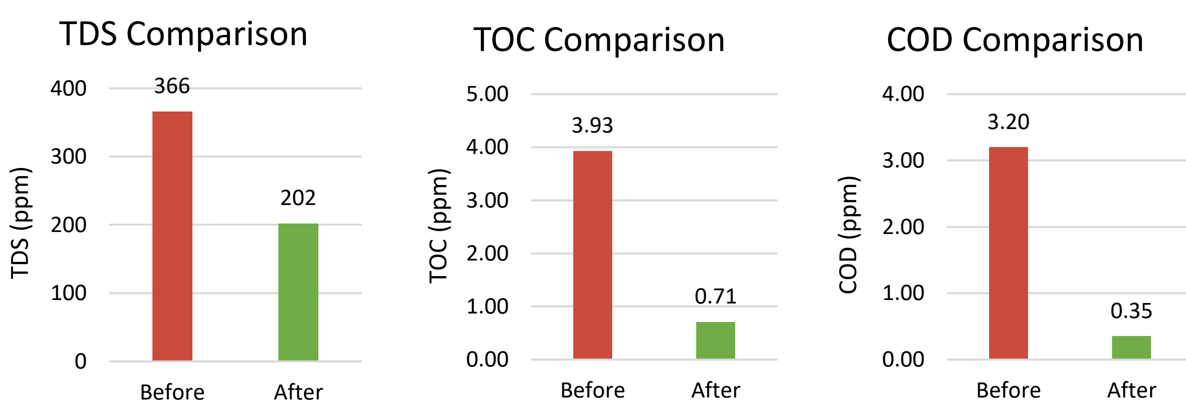


Fig. 9 Filtered water from Corpus Christi water department before and after comparison.

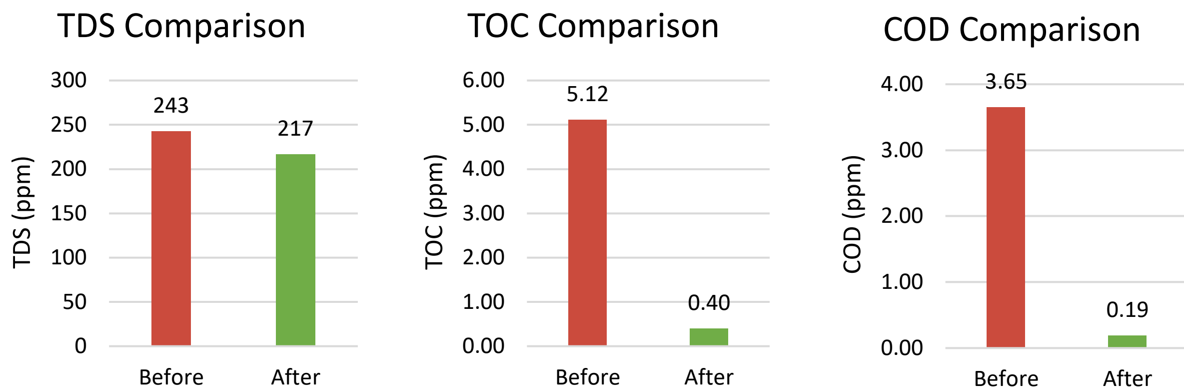


Fig. 10 Water from Corpus Christi gas station bathroom sink before and after comparison.

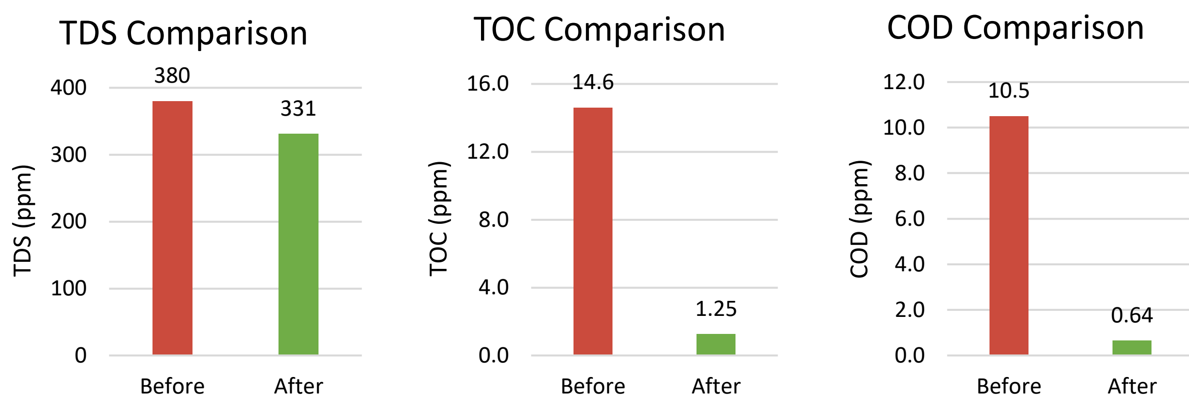


Fig. 11 Unfiltered water from Corpus Christi water department before and after comparison.

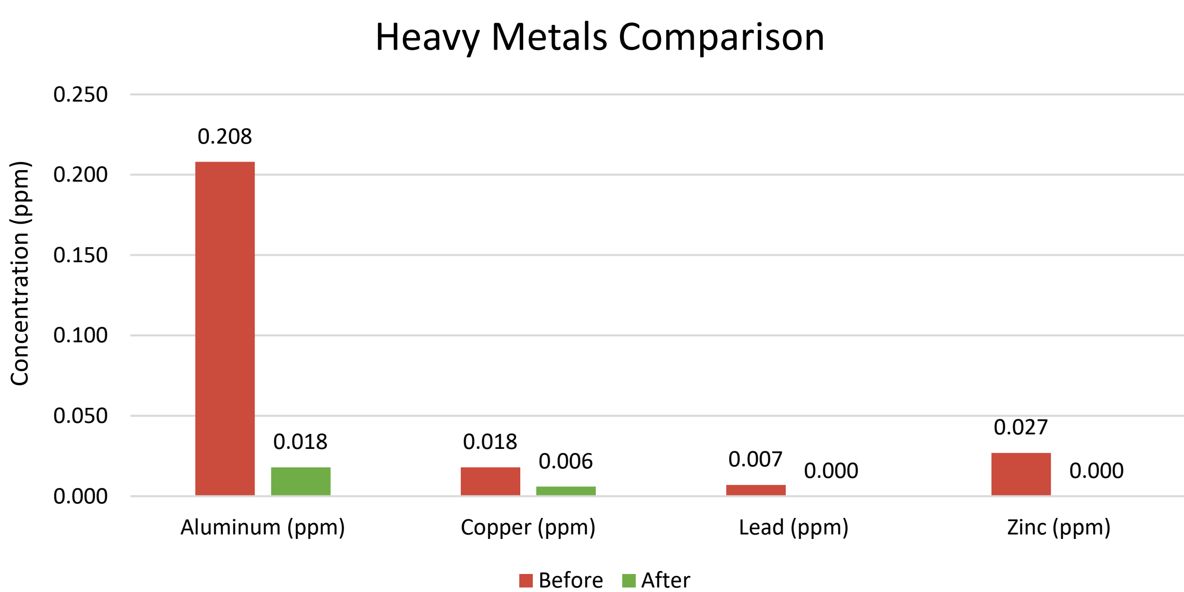


Fig. 12 Before and after filtration comparison for aluminum, copper, lead, and zinc.

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