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The Bottling Craze: Exposing the Environmental Effects of Bottled Vs. Tap Water

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Introduction: Is Bottled Water Really So Great?

Americans take water for granted on a daily basis when they can go to the vending machine or grocery store and pick up a cold bottle of water to enjoy. What people do not normally consider is where this water comes from or what chemicals are used to make the plastic bottle. Some may believe that they are doing something noteworthy when choosing a brand like Poland Spring that boasts "30% less plastic" used in their product, along with choosing a brand that uses smaller labels to save paper.[1] The Poland Spring website claims that they are "drop by drop…one of the most efficient users of water among the US beverage industry" and the interesting word choice here is "users."[2] Some critics of the bottling industry question whether the large companies are just "using" water or exploiting the natural resources and ruining business relations within the small town water sources. Water snobs also mention a different aftertaste in tap water from the purification by chlorination, but can one really tell the difference in a blind taste test? The water companies also disregard reusable options, such as Nalgene bottles that are useful for an on-the-go lifestyle instead of plastic that is recyclable but not always recycled.

The Water Cycle, Pollution, and Water Systems History

The Water Cycle. The root of the issue of water quality stems from where our water originates. The hydrologic cycle, or water cycle, depends on the sun by evaporating water from land sources and the ocean. The water vapor in the air condenses and precipitates, falling onto the land, into the streams, or back into the ocean, ultimately being recycled. The snow that precipitates may not have as fast of a turnover rate as rain and remains frozen

[1] Poland Spring Direct, Be Green
[2] Poland Spring Direct, Be Green https://eservice.polandspring.com/pages/ps/BeGreen.aspx
https://eservice.polandspring.com/pages/ps/BeGreen.aspx

on the ground for the winter or as glaciers. Eventually, this snow will melt and return to the oceans and be recycled back into the water cycle.

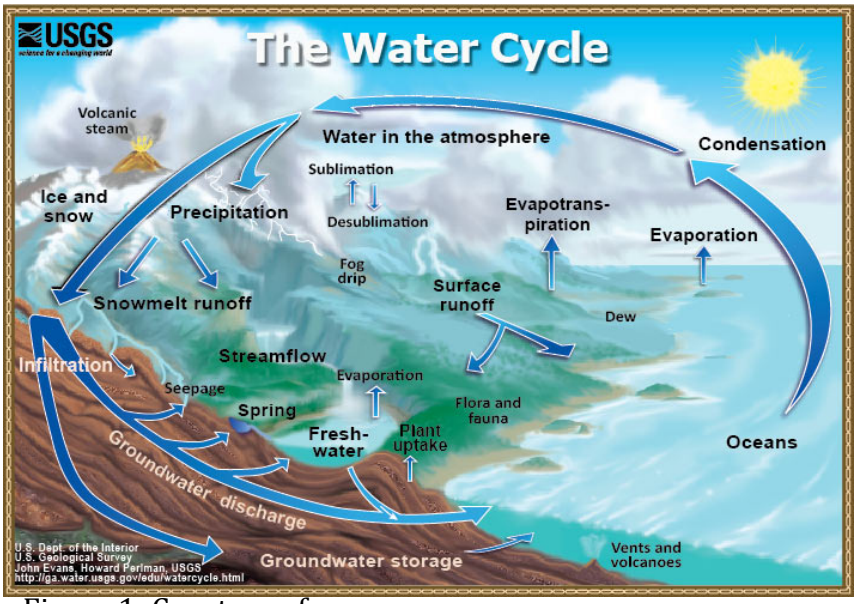

Figure 1: Courtesy of http://ga.water.usgs.gov/edu/watercycle.html

Groundwater consists of a small part of the hydrologic cycle, but is an important part of how water circulates continuously. Less than "one percent of the water on Earth is groundwater," originating from rainfall.[3] Water soaks into the ground and moves through the zone of aeration into the saturated zone, where the rainwater joins flowing groundwater or flows to the surface into streams and rivers. The zone of aeration consists of regolith or bedrock that contains pore spaces, which can contain water but is not saturated. The rate of the flow of groundwater depends on the "porosity and permeability" of the rock or sediment it is flowing through.[4] The porosity, or open space between the rock particles, is dependent upon the shapes of the particles themselves and the compactness. The permeability, or the ability of fluid to travel, depends upon the path shape. Groundwater will tend to move slower if it has to travel in a crooked path versus a straight path. In order to obtain groundwater for personal use, one must reach the saturated zone underground. Springs, which are used by bottling companies, are flows of groundwater that flow naturally at the

[3] Skinner page 384
[4] Skinner page 386

surface.[5] Wells on the other hand intersect the water table underground and the amount available is affected by the height of the water table. When a well is initially drilled a "cone of depression" surrounds the well, which is a depression in the water table that will eventually balance. However, "wells pumped for…industrial uses withdraw so much water that the cone can become very wide and deep," lowering the surrounding water table and affecting the amount of available water for use.[6] Extraction of groundwater becomes detrimental to the environment when the amount withdrawn exceeds the natural recharge of the region. Although groundwater travels, it can be seen as nonrenewable in some places because it can take to long to replenish the area if too much pumping occurs, leaving water sources depleted. If too much water is withdrawn by large industries for bottling, it can lead to streams and springs drying because the water table would be lowered and would no longer intersect at the surface.

Pollution. Industrialized nations take clean and safe drinkable water out of the tap for granted. In the past, drinking water was severely contaminated and was not adequate for human consumption. Human and industrial waste products today have also contaminated water sources. Impurities are added to water "in the atmosphere, or picked up in streams from rocks and sediments, are filtered out by plant growing along streams and wetlands that absorb organic material and minerals."[7] Weathered rocks release minerals into the water, such as "chlorides, sulfates, bicarbonates of calcium, magnesium, sodium, potassium, and iron".[8] The amounts of each mineral vary depending on the composition of the bedrock. Water high in carbonate concentration is termed "hard water"

[5] Skinner page 389
[6] Skinner page 390
[7] Traer, Robert page 189
[8] Skinner page 396

and forms rings and deposits found around faucets and showerheads. Pollution in groundwater can also be generated by sewage. Drainage from septic tanks along with sewers can pass through the large pores in the rock particle space and travel for long distances, remaining polluted. If the pollutant passes through a finer grain rock, the water can be purified more quickly. Human waste and industrial waste can also contribute to contaminated waterways. When human garbage in a landfill is covered with dirt, water percolates down, carrying contaminates into the groundwater supply.

The Clean Water Act of 1972 was enacted to "restore and maintain the chemical, physical, and biological integrity of the nation's waters."[9] Our waters need to be protected from the many pollutants that sacrifice the integrity of our natural resources. Pollution can originate form point source pollution or nonpoint source pollution. Point source pollution concerns pollution released into the environment from factories, mining, landfills, and "leaking sewage treatment facilities."[10] On the other hand, nonpoint source pollution involves storm water runoff, which carries pollutants to surface waters from roadways, construction site, and agricultural fields into the storm gutters and streams, which eventually resurface in our water supply. Surface water seeps into groundwater, which eventually reaches aquifers. There are ecological limits to what our environment can naturally do to monitor water quality. "About 97% of the liquid freshwater on earth is underground" and this supply is becoming a nonrenewable resource since it takes "1,400 years to replenish an underground aquifer."[11] Both of these types of pollution are a major problem in regards to our water quality.

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[9] Traer, Robert page 189
[10] Traer, Robert page 190
[11] Traer, Robert pages 191-192

Pollutants can be attributed to other problems besides the contamination of ground and surface water, such as declines in animal population (from DDT) and introduction of cancers. Therefore, industrialized countries must be concerned with waste management of highly toxic chemicals. If wastes on the surface are not controlled, contamination seeps into surface waters, polluting the hydrologic cycle. Contamination from pollutants such as DDT became a major contributor to sparking environmental awareness. By 1964, Carson "initiated a transformation in the relationship between humans and the natural world and stirred an awakening of public environmental consciousness".[12] Carson's *Silent Spring* challenged the government to examine the effects of chemicals put into the environment before long-term consequences were determined because many were deemed toxic after years of contamination. Carson comments how "chlorinated hydrocarbons and organic phosphorous insecticides altered the cellular process of plants, animals, humans".[13] This is detrimental to our water supplies and has contaminated our drinking water in the past. *Silent Spring* served the purpose of opening up citizens' eyes to environmental pollutants. She comments that "…in a very real and frightening sense, pollution of the ground water is pollution of water everywhere," which is true because all running water was at some point groundwater in the hydrologic cycle.[14]

Water Systems History. We notice that "…humans with their new activities began to put their mark on the environment—on a small scale at first but gradually more and more…" but how did our water systems evolve to the state that they are today?[15] The Ancient Greek cities were "known for their spectacular public fountains fed by springs and

[12] Carson page x
[13] Carson page xv
[14] Carson page 42
[15] Kandell, Robert page 190

dedicated to gods or heroes".[16] Rome featured nine aqueducts that brought water to thirty nine fountains and five hundred and ninety one public basins, some of which still function today. [17] Instead of our private use of water today in individual buildings, the fountains served as gathering spots to share local news and for social interaction. Bathing in public waters was not seen as taboo but more common practice. Although these water systems were originally successful at providing water, in the middle of the 19th century the aqueducts and fountains began to fall into disrepair. At this point, the water sources were not respected and the rivers "flowing through towns and cities were little better than open sewers of human waste and garbage".[18] Diseases quickly spread because of these unclean conditions, killing thousands. At first, the source of the diseases were unknown while a massive wave of cholera swept from Scotland to Britain and then reaching New York City through ports. Cholera is a disease that consists of vomiting and diarrhea and must be treated immediately with rapid rehydration or antibiotics, although the source of the disease can be eliminated with sanitation systems and water purification.[19]

As more people were dying from cholera, advances in the sciences were made to find the source of the problem. In 1854, the Italian scientist Filippo Pacini pinpointed the bacteria responsible for cholera and determined that it was transmitted through contaminated water, but his work was not taken seriously until 1883 when German physician Robert Koch rediscovered it.[20] New efforts were made in the sciences to learn more about sources of these water-borne diseases and how to prevent them. This led to the

[16] Gleick, Peter page 18
[17] Gleick, Peter page 18
[18] Gleick, Peter page 21
[19] Kandall, Robert page 200
[20] Gleick, Peter page 25

implementation of more modern water practices, such as sewage systems, water treatment, and the introduction of piping systems to protect the quality of drinking water. For example, as the population of Paris grew, the demands for the availability of drinking water also increased. The construction of the Canal de l'Ourcq along with pumps along the Seine and drilling of wells helped to make drinking water more available to the public.[21]

The Parisian chemist Claude Louis Berthollet discovered chlorination of water as a purification technique in the late 1700s. At the time, his discovery of sodium hypochlorite was marketed as a laundry bleach, and it would take a hundred years before chlorine based chemicals would be used for water disinfection.[22] Although we have seen positive improvements in the water quality through chlorination, the chlorine in the water also has some negative effects. A basic science principle is that chlorine is a reactive species by possessing the quality of being a good leaving group. Therefore, chlorine can react with organic materials found in the water to create harmful species for human consumption. An example of these organochlorine compounds is "trihalomethanes" (THMs), which are potentially carcinogenic.[23] The caveat in regards to using chlorine disinfection is finding the right level to kill harmful microbes and bacteria while but still maintain a safe level for human consumption. The simplest and easiest way to obtain unpolluted water is to have an unpolluted source.

Water Pollution Prevention

Case Study: The Fight for the Croton Watershed. A watershed is an area of land where water flows across or under the area on its way to a larger body of water. The water

[21] Kandall, Robert page 201
[22] Kandall, Robert page 200
[23] Kandall, Robert page 200

path flows to the lowest point, traveling across different materials, such as lawns, malls, and city streets.[24] The problem with following any path is that the water can carry pollutants, such as oil, gas, and other pesticides, collecting in the reservoir to be used as a source of drinking water. The Croton Watershed provides drinking water to Westchester, Putnam County and parts of NYC. The EPA has ordered the New York City government to build a one billion dollar chemical filtration plant to protect the quality of the drinking water although the water in the Croton system already meets EPA standards.[25] In fact, the imposed filtration system may even harm the quality of the drinking water. In the documentary *The Fight for Croton Watershed—Protection vs. Filtration,* there is a push for controlling development and protecting the water supply at its source instead of developing a new purification system. Construction destroys the natural surroundings and therefore removes the natural filters on the water. With land degradation, rain is no longer absorbed into the soil to flow down into the zone of saturation, and therefore does not add to the groundwater supply. Instead, the surface water carries pollutants and will eventually collide with another source of running surface water, but this will add pollutants to the drinking supply. Development in the land area of the watershed is the source of most of the drinking water pollution. The Croton Watershed documentary focuses on the fact that if we keep building, the quality of our drinking water will be in serious trouble and will become unsafe to consume.

The chemical filtration processes in which unwanted particles are removed from the water and chemical treatment is added, such as alum, ozone, and chlorine, can possess

[24] Rose, David H., DVD 1999
[25] Rose, David H., DVD 1999

harmful side effects.[26] David Gordon, an attorney with the Hudson Riverkeeper, comments how filtration is expensive and will not remove dissolved chemicals. The filters have the capacity to remove physical objects like bacteria and larger particles, but viruses pass through the expensive filtration systems. For example, Robert F. Kennedy, Jr., senior attorney with the Natural Resources Defense Council states that road salts and trihalo methanes harm our water supply.[27] He highlights the important fact that with these pollutants traveling into our water supply, we will have more expensive water at a lesser quality in the future if we do not protect source water. Prevention instead of building expensive water purification plants is more cost effective and better for our environment in the long run. The EPA's proposal for a one billion dollar plant will not simply cost that price, but will have additional maintenance costs over time.

Milwaukee Water Works serves as an example of unmaintained filtration plants. Carrie M. Lewis, the superintendent of Milwaukee Water Works says that she prefers to filter water instead of protecting source water, but these chemical filtration plants can and will fail. The Milwaukee River Basin provides drinking water for 850,000 people in the area. In 1998, the city suffered a water crisis where the water was contaminated, causing sickness in over 400,000 residents and killing over 100 people.[28] Because aging plants from the 1960s were not properly maintained and should have been upgraded, contamination from these plants ensued. Ozone disinfection was added as a purification practice in 1998, but ozone at the time was not as well characterized as chlorine filtration practices. Not all of the people in power agree with Lewis' stance on water filtration practices. On the other

[26] Rose, David H., DVD 1999
[27] Rose, David H., DVD 1999
[28] Rose, David H., DVD 1999

hand, Kathleen Blair, an epidemiologist with the Milwaukee Health Department would have rather spent money on watershed protection rather than building a water filtration plant. She believes that it is more environmentally conscious to protect the environment through "more common sense low-tech issues than end of the pipe treatment."[29]

Along with considering whether or not we have a responsibility to protect the source water, we also have to consider one's rights concerning personal and public land use. The way to protect our water system is by protecting the water source, but some feel personal land use should not have regulation and some disregard the affect of personal property construction on the surrounding environment. Robert F. Kennedy, Jr. also states that one does not have a constitutional right to use private property in a way that will injure others.[30] If protection of drinking water is a concern, then regulation of building projects must be conscious to protect the natural landscape. If private lots are fully developed, then the land becomes completely degraded and affects the quality of the natural water purification system. The EPA and NY EPA refused to be interviewed for the Croton Watershed documentary, but the EPA website offers a wealth of information regarding drinking water practices.

The End of Suburbia: Oil Depletion and the Collapse of the American Dream discusses the history of suburban sprawl and how this has affected our environment and human quality of life. In the 1950s, the suburban lifestyle originated with the best of intentions, but quickly cultivated a lifestyle dependent upon individual and family consumption. Mass transit was initially not an available option in the suburbs, which is why our society quickly became dependent on oil. "We are a society addicted to oil and we do not want to hear that

[29] Rose, David H., DVD 1999
[30] Rose, David H., DVD 1999

it will run out".[31] With our high demands on the environment, the American dream of moving to the suburbs does not exemplify a sustainable way of life. Suburban sprawl, along with other point and non-point pollution sources are responsible for the biggest impacts on watershed quality.

James Howard Kunstler, author of *The Geography of Nowhere: The Rise and Decline of America's Man-Made Landscape,* an author interviewed for *The End of Suburbia* documentary, emphasizes the fact that people will fight to maintain the entitlements of suburbia, even if this causes political upheaval and a disregard for watershed quality. He says that "politicians will try to procure more petroleum in some way" and that Americans will elect "maniacs" that will promise to keep their suburbs, even if this is not feasible.[32] Richard Heinberg, author of *The Party's Over: Oil, War, and the Fate of Industrial Societies* comments on how we have "created a new system of habitation" with people living farther from necessities and work because they have access to personal transportation by the means of cheap energy.[33] The suburbs would not have been possible without cheap oil, but does it make it ethically right for companies to destroy our environment and degrade our water quality with oil overuse? When evaluating the impact of shipping bottled water in from foreign countries such as Evian and Fiji waters, we should realize that this has a detrimental effect on our environment. Why do people and companies feel the need to ship bottled water when there is perfectly adequate drinking water available locally and at a significantly lower price? Bottling companies must ship and distribute farther from source water, which has negative environmental implications.

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[31] Greene, Greg The End of Suburbia 2004
[32] Greene, Greg The End of Suburbia 2004
[33] Greene, Greg The End of Suburbia 2004

Smart Growth Policies and Practices. In order to combat the negative environmental implications of suburban sprawl, control policies known as "smart growth" policies are becoming effective in communities around the United States. Elements of smart growth include compact neighborhoods, which attracts more people and businesses. The creation of town centers allow for people to run errands by walking or biking, instead of using personal cars as transportation. Compact neighborhoods limit typical suburban design including detached houses and strip malls. Choosing smart locations to build greener communities creates "access to jobs, housing, restaurants, and parks for recreation," increasing the overall quality of life in the area.[34] Towns and cities that include pedestrian and bicycle friendly design reduces carbon emissions while at the same time fosters healthier lifestyles. When development prohibited areas are set aside, it provides fresher air and cleaner water with the reduction of possible pollution in these designated areas. Green buildings and infrastructure at the same time are more environmentally efficient, which saves on energy costs as well as protecting our environment.

Smart Growth America is an organization that advocates smart growth solutions to fight suburban sprawl and to save money by bringing together neighborhoods and fostering growth of local businesses. New York City councilmember Brad Lander focuses on building better neighborhoods by applying smart growth policies. He believes that neighborhoods' ultimate aims are increasing the quality of life in their communities. To Lander, this means "economic development, more walkable, livable streets, investing in infrastructure with long-term goals in mind…[and] a more sustainable future."[35] Through

[34] http://www.nrdc.org/sustainable-communities/default.asp

[35] www.smartgrowthamerica.org

smart growth, towns and cities can support local economics while at the same time protecting the environment. The American dream is a ideal that still lives strong in our culture, but there needs to be some adjustments made to make this ideal sustainable. At the core of the American dream is a neighborhood that is "beautiful, safe, affordable, and easy to get around" and this is obtainable through smart growth practices.[36] Empire State Future, a coalition dedicated to smart growth and sustainable development in New York, has also noticed new trends in young people today towards city living. They state that in 2015, around 4.2 million 25 year olds will enter into the housing market. "If anywhere 77% of these young people do choose the urban core, they will start to trigger fundamental changes to a half-century of U.S. land patterns, home types, locations and prices."[37] The young adults will be replacing the older members in society that have previously lived in the suburbs in single-family homes instead of apartments. This change in the living style preferences will help to foster smart growth and will be a positive move towards more sustainable living practices.

A major concern in regards to our water quality is the pollution of stormwater runoff, which stems from unsustainable development practices. Smart growth preserves the open spaces that we have left to aid in natural filtration of runoff. When we build densely or re-use already developed land, the quality of our streams and reservoirs does not become further degraded. The Sierra Club highlights the fact that "as reliance on cars and pavement of more and more roads increases" during suburban sprawl, the smog and

[36] http://www.smartgrowthamerica.org/what-is-smart-growth
[37] http://www.empirestatefuture.org/geography/state/there-is-nothing-inevitable-about-american-suburbia/

pollution from water runoff increasingly affects our environment.[38] A positive of smart growth is that it requires less imperious paved surfaces in towns, preserving natural filtration processes. By building close by, it "means less paved roads are required to get between those locations, and less pavement means more open space."[39] Building on land that was previously developed, reduces carbon emissions and other air pollution, which reduces the amount of pollution that enters our water supply through polluted rainwater. The Sierra Club also comments that if developers are required to pay impact fees to cover costs of environmental along with property taxes, the developers may begin to use smart growth practices more readily. Smart growth improves our water quality, but in areas that do not adopt these policies, we need to improve our drinking water standards and purification techniques.

Water Filtration and Purification

EPA's Drinking Water Practices. Although *The Fight for Croton Watershed—Protection vs. Filtration* documentary has an alarming tone in regards to the quality of our water supply, the EPA boasts that the "United States enjoys one of the best supplies of drinking water in the world".[40] Congress passed the Safe Drinking Water Act in 1974, which regulates public drinking water supply to make sure that consumers can obtain water that upholds health standards. The EPA outlines their standard treatment process, but this process may vary depending on the quality of the water entering the plant. The steps are as follows: coagulation, sedimentation, filtration, disinfection, and storage.[41] In the coagulation and sedimentation steps, alum and other chemicals are added to the water to

[38] http://www.sierraclub.org/sprawl/overview/
[39] http://www.smartgrowthamerica.org/issues/environment/
[40] www.epa.gov/safewater page 1
[41] www.epa.gov/safewater page 8

attract dirt to the sticky particles called "floc", which will become heavy and sink to the bottom.[42] The problem that some critics see with these steps are that in further purification, the alum and other chemicals added are not fully removed from the water supply and in fact contaminate instead of purifying it. In the disinfection step, the EPA states that a "small amount of chlorine is added…to kill any bacteria or microorganisms that may be in the water".[43] Chlorine is an effective disinfectant and at low levels it is not harmful in the drinking water. It may be alarming to consumers that some pollutants flow into our reservoirs that are later used for drinking, but the government-imposed regulations are more stringent on public water supply than bottling companies. There are potential risks to drinking bottled water because "bottled water is not under the same testing and reporting as water from a treatment facility".[44] Water bottled and sold within the same state is not subject to any federal standards, which is extremely alarming.

Purification Practices. A common form of pollution control is through a system of sewers and wastewater treatment plants. The water is treated to remove large particles and other obvious pollutants and then the purified water is returned back to the larger water supply. There are three categories of wastewater treatment: primary, secondary, and tertiary or advanced.[45] Primary treatment practices consist of separating solid materials from water by sedimentation or removal of floating particles. Once the grit and other particles have been removed, the water is treated with chlorine gas before discharge into a stream or river. The purpose of adding chlorine is to destroy bacteria, but negative health effects have also been discovered from chlorine residue remaining in the water supply. In

[42] www.epa.gov/safewater page 8
[43] www.epa.gov/safewater page 8
[44] www.epa.gov/safewater page 15
[45] Stoker, Stephen H. Environmental Chemistry page 179

order to further purify the wastewater, secondary treatment is also performed through " trickling filter and activated sludge processes."[46] Secondary treatment eliminates harmful bacteria from water, but it does not effectively remove dissolved organic and inorganic compounds.

Although there are a few different tertiary purification techniques in use today, each has its limitations. The four commonly used purification techniques are activated carbon filters, ion exchange, reverse osmosis, and distillation. Activated carbon filters are most often identified as Britta filters which many families keep in their refrigerators. The activated carbon filter removes some organic contaminants that are the cause of bad taste or odor and may remove chlorination byproducts, cleaning solvents, and pesticides.[47] The filter removes the organic pollutants by adsorbing to the surface of the carbon.[48] The downside of activated carbon is that it does not adequately remove nitrate, bacteria, or dissolved minerals. These filters must also be replaced at regular intervals in order for them to efficiently remove contaminants.

Ion exchange units with activated alumina remove dissolved minerals so that it serves as a water softener and removes other unwanted compounds such as radium, barium, and fluoride.[49] The problems involved with an ion exchange unit is that if the water contains oxidized iron or iron bacteria, the unit's resin will easily become clogged and lose its ability to soften the water. The upkeep on this unit requires regeneration with salt periodically.

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[46] Stoker, Stephen H. Environmental Chemistry page 180
[47] Water on Tap www.epa.gov/safewater page 16
[48] Stoker, Stephen H. Environmental Chemistry page 181
[49] Water on Tap www.epa.gov/safewater page 16

Reverse osmosis removes a longer list of contaminants from drinking water. It is capable of removing nitrates, sodium, and other dissolved compounds. Similar to the activated carbon filter, reverse osmosis is adequate at removing "foul tastes, smells, or color."[50] Although reverse osmosis can reduce the levels of pesticides, dioxins, and other harmful petrochemicals, this technique does not remove all of the inorganic and organic pollutants found in water and therefore still leaves our water subpar.

A distillation unit efficiently "removes nitrates, bacteria, sodium, dissolved solids, most organic compounds, heavy metals, and radionucleides" while also killing bacteria.[51] The limitations of distillation are that it does not remove some organic pollutants and certain pesticides. A major concern of distillation is that when the unit becomes inactive, the bacteria can recolonize on the cooling coils, thus there is a recontamination of the purified water, minimizing the removal of harmful organic pollutants.[52]

It is important to keep in mind that each purification technique has its benefits and limitations, and that one purification technique cannot remove every contaminant. The EPA also presents the National Primary Drinking Water Regulations in table form in the *Water on Tap* report. This table includes important information regarding the allotted amounts of contaminant allowed in the drinking water supply, along with the potential human health effects and common sources of contamination.

How Dendrimers Can Help. Pharmaceutical pollutants that are not covered by the primary drinking water standards "have been shown to survive the treatment process,

[50] Water on Tap www.epa.gov/safewater page 16
[51] Water on Tap www.epa.gov/safewater page 16
[52] Water on Tap www.epa.gov/safewater page 16

which is generally used in publically operated treatment systems".[53] Therefore, there is a need for a new kind of purification technique to remove these harmful organic pollutants. Dendrimers are a viable new alternative for the removal of organic pollutants from water environments. These macromolecules can be used as "nanosponges" to remove small organic pollutants from drinking water that typically are not removed through standard purification techniques. Dendrimers are monodisperse macromolecules prepared in a stepwise fashion from monomer units and a core molecule.[54] These monomers are located in layers called generations that surround the core. The figure below shows two representations of what a dendrimer looks like in simplified form.

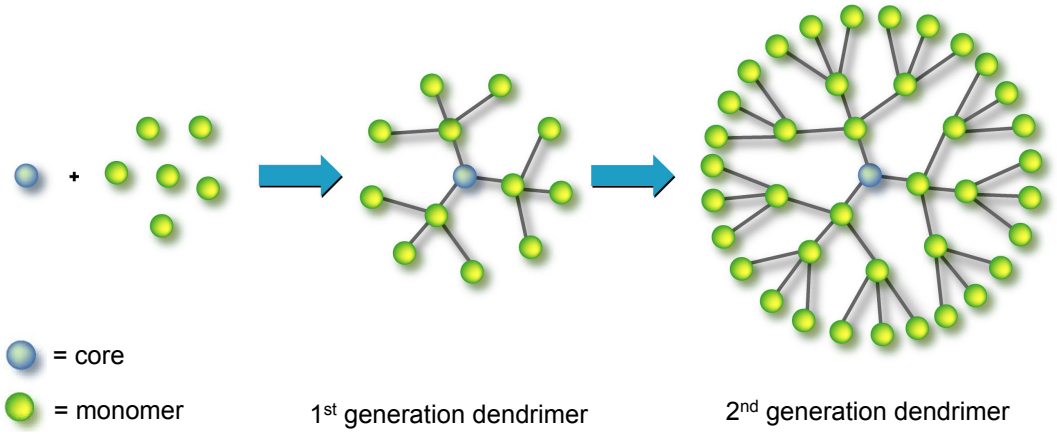

Figure courtesy of Tracey, et al.

As you can see, the first generation dendrimer is a smaller structure and therefore has less pore space than the second generation dendrimer. The rigidity increases with an increase in generation size and is also affected by the type of monomer repeating unit, the type of

[53] Traer, Robert page 195
[54] Frechet, Jean M. Dendrimers and Other Dendritic Macromolecules page 3714

bond, and the degrees of freedom.[55] The cavities or pore spaces within the molecule can interact with guest molecules and encapsulate them within the dendrimer. The rigidity is an important characteristic because of how we view the encapsulation process. The dendrimer is thought to wrap around the pollutant or can have a surface interaction with the pollutant. The internal pore spaces of dendrimers determine the microenvironment of nanocavities while the external groups at the periphery determine the behavior of the molecule with the external medium.[56] As seen in the figure below, small organic pollutants can fit within the cavities and be encapsulated by the dendrimer.

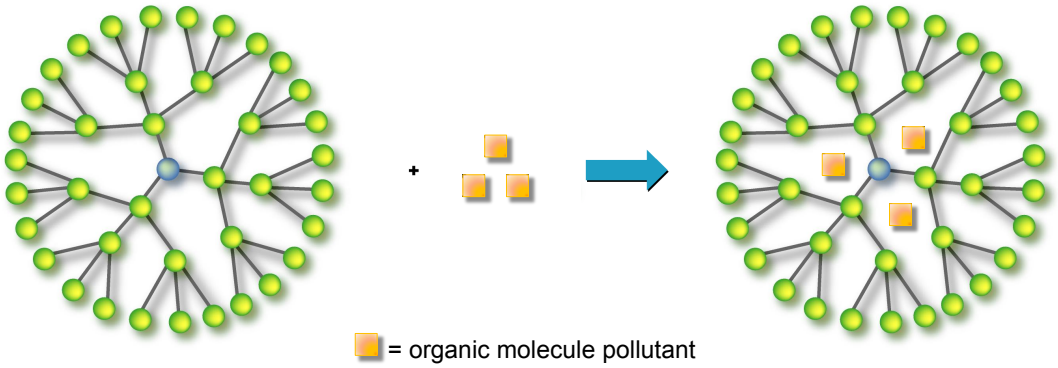

Figure courtesy of Tracey, et al.

By varying the type of monomer unit, dendrimers can be prepared with different physical and chemical properties. The properties of the dendrimer depend also upon the structural characteristics of the core, branches, and surface end-groups.[57] One can also change the monomer between generations to determine if the addition of a different monomer group, such as an amine or a different position of the ether linkage has an effect upon the encapsulation.

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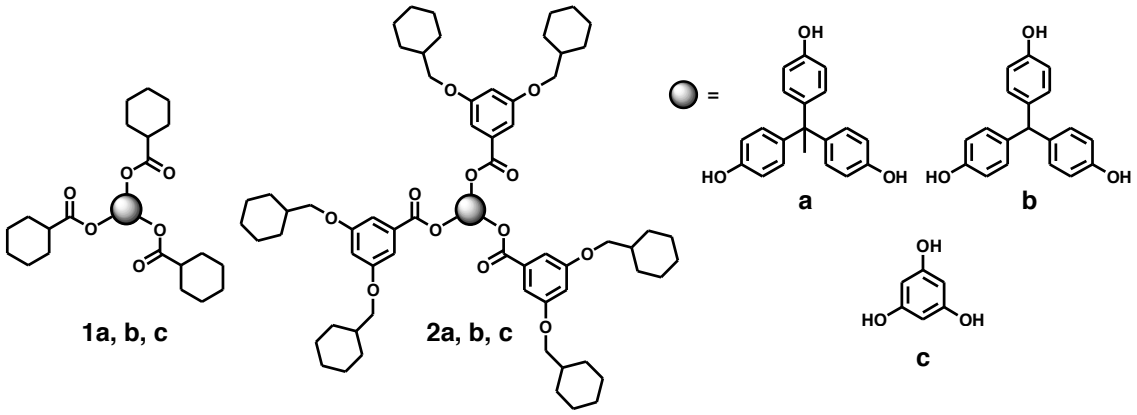
[55] Frechet, Jean M. Dendrimers and Other Dendritic Macromolecules page 3714
[56] Arkas, Michael Functional Dendrimeric "Nanosponges" 2003 page 2844
[57] Arkas, Michael. Organic/Inorganic Hybrid Filters page 2771

The type of dendrimer that I synthesize in Dr. Amy Balija's organic laboratory is the cyclohexane based dendrimer. The figure below is a chemical drawing of what the zero and first generation dendrimers look like.



Caption: The gray sphere is a representation of the three cores used in our lab, cores a, b, and c above. The diagram above labeled 1a, b, c is a drawing of a zero generation dendrimer. Diagram 2a, b, c is a drawing of the first generation dendrimer.
Figure courtesy of Tracey, et al.

Three different types of dendrimers are synthesized, which differ by the core used. Core a and b appear to be similar, but upon closer examination core a contains a methyl handle off of the central branching point. The methyl handle is significant because it could have an effect upon the encapsulation properties of the overall molecule. Core c is much smaller than the other two cores to see if the size of the core has an effect on encapsulation. The way that we can tell whether or not the dendrimer encapsulates the pollutant from water is examining the encapsulation.

Synthesis and Evaluation of Cyclohexane Based Dendrimers. The synthetic schemes of how to synthesize the zero, first, and second generation dendrimers are show below:

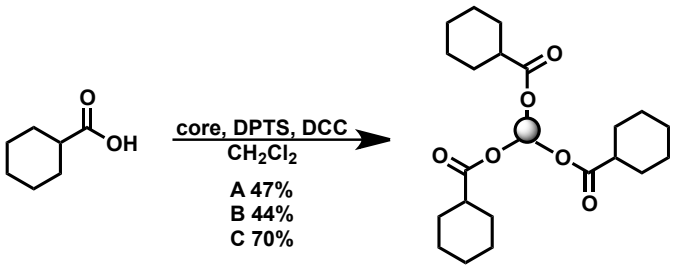


Figure: Synthetic scheme of G_0 cyclohexane based dendrimer. Modified DCC coupling reaction.

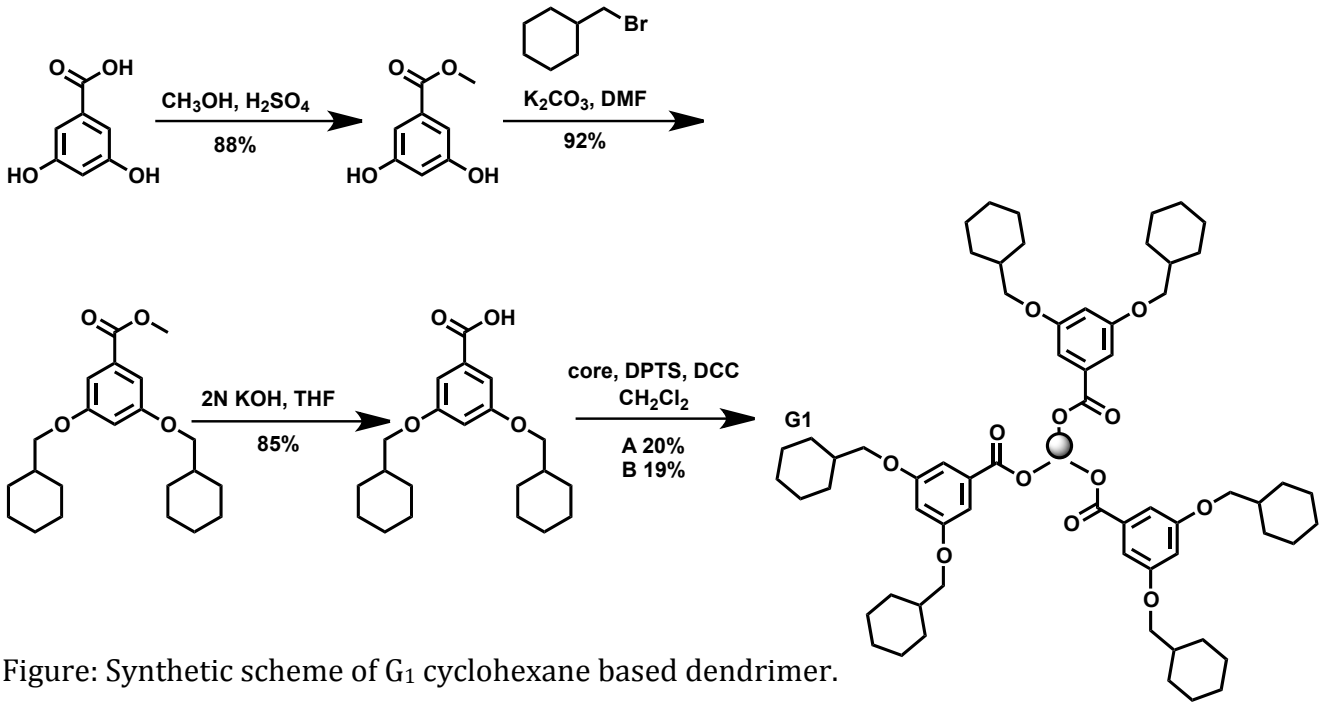
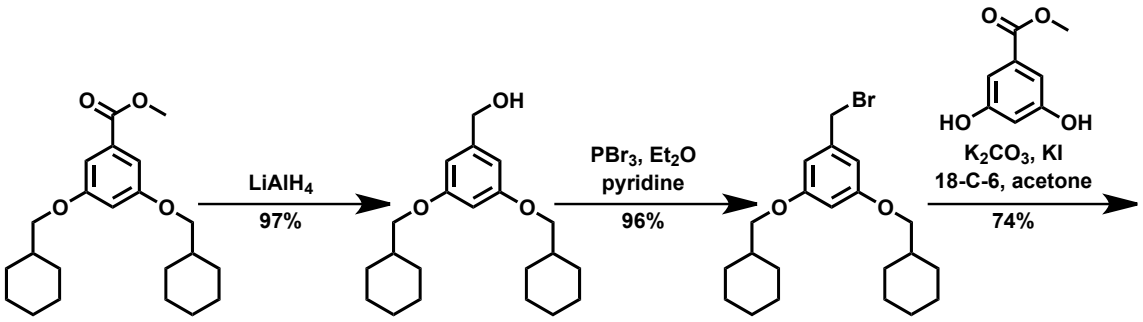


Figure: Synthetic scheme of G_1 cyclohexane based dendrimer.



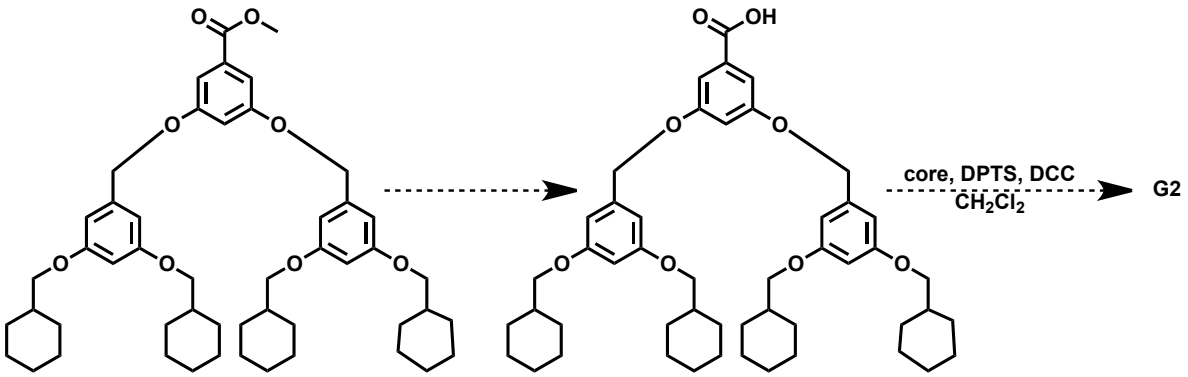


Figure: Synthetic scheme of G_2 cyclohexane based dendrimer.

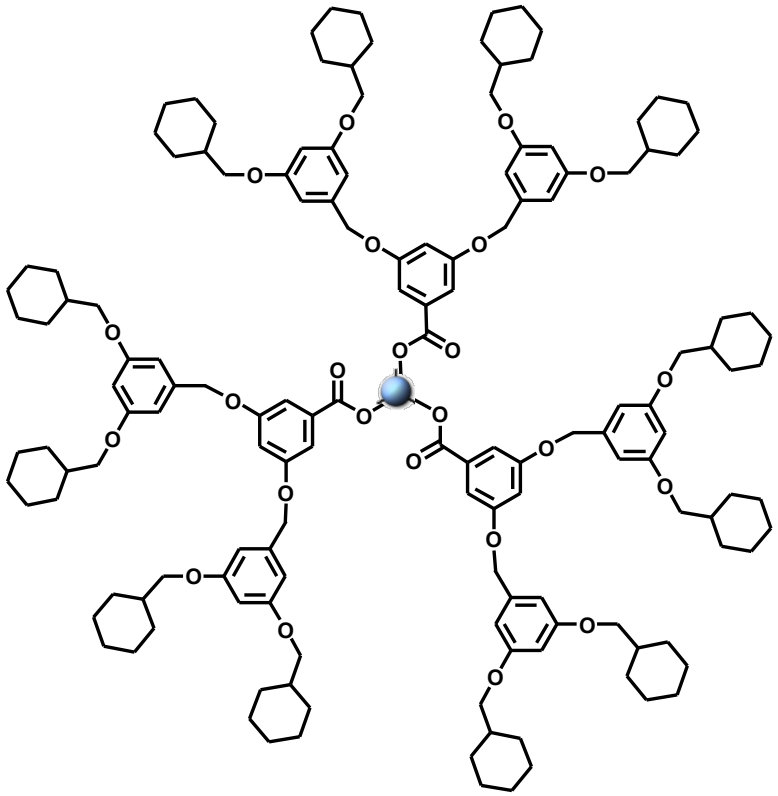
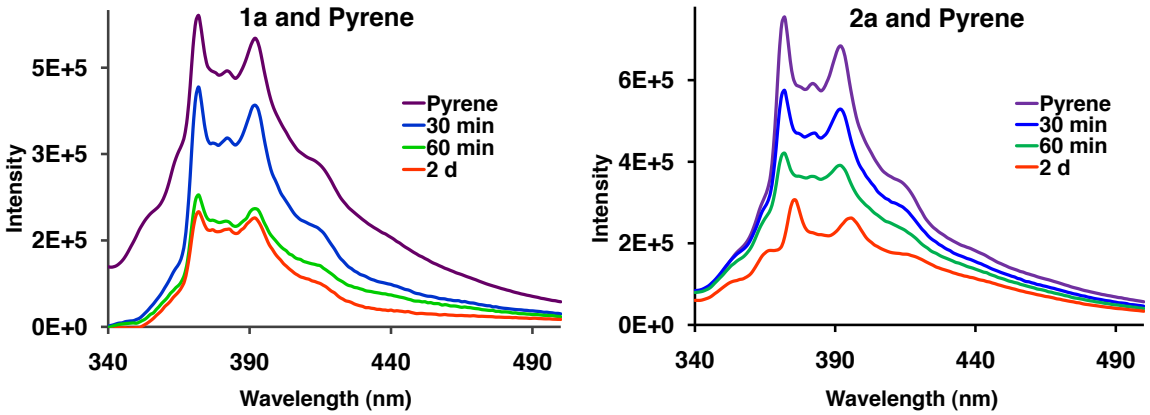


Figure: simplified drawing of G_2 dendrimer.

Studies were performed to examine the dendrimer's ability to encapsulate polycyclic aromatic hydrocarbons (PAHs). A common PAH is pyrene, which absorbs at 325 nm. Thin films of each dendrimer were prepared, both zero and first generation dendrimers, by evaporating a 0.02mM solution containing the macromolecule in dichloromethane. Aliquots of a saturated solution of the PAH were then introduced to the

dendrimer films. Samples were removed at three different time intervals: 30 minutes, 60 minutes, and two days, and analyzed by fluorescence spectroscopy.



This raw data corresponds to the G0 and G1 a core dendrimers.
Figure courtesy of Tracey, et al.

A decrease in fluorescence intensity indicates that the dendrimer is doing its job and encapsulating or interacting with the organic pollutant. The encapsulation studies of cyclohexane based dendrimers initially show that these dendrimers can entrap pyrene and would serve as a new way to remove organic pollutants from our drinking water. Current work is focusing on preparing the second generation cyclohexane based dendrimer to determine whether or not size impacts the encapsulation ability.

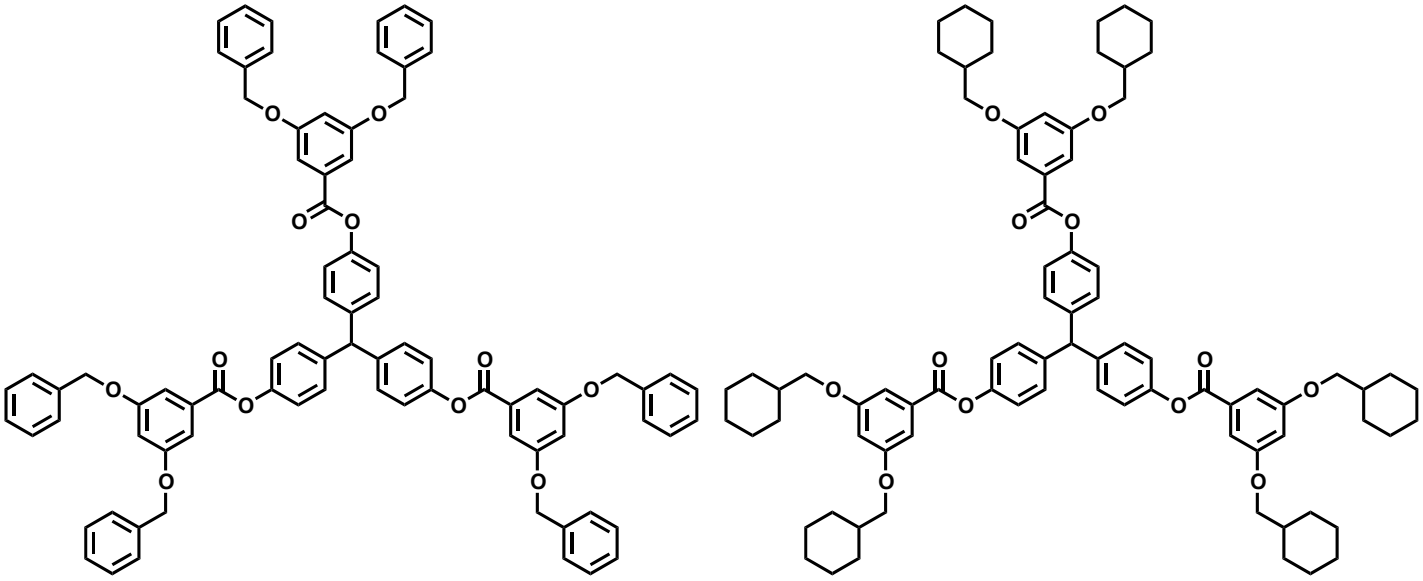


Figure: Comparison of the G_1 benzyl ether and cyclohexane based dendrimers. The difference here is at the porphyry of the molecule. The benzyl ether contains benzene rings instead of cyclohexane rings.

We can also compare the encapsulation capabilities of the cyclohexane based dendrimers to a standard, such as benzyl ether based dendrimers. In the figure above, a comparison can be made between the two G_1 dendrimers. The difference of the conjugation of the ring at the porphyry is significant because the cyclohexane rings are more nonpolar, which we would assume would cause a greater decrease in the intensity seen in the absorption spectra.

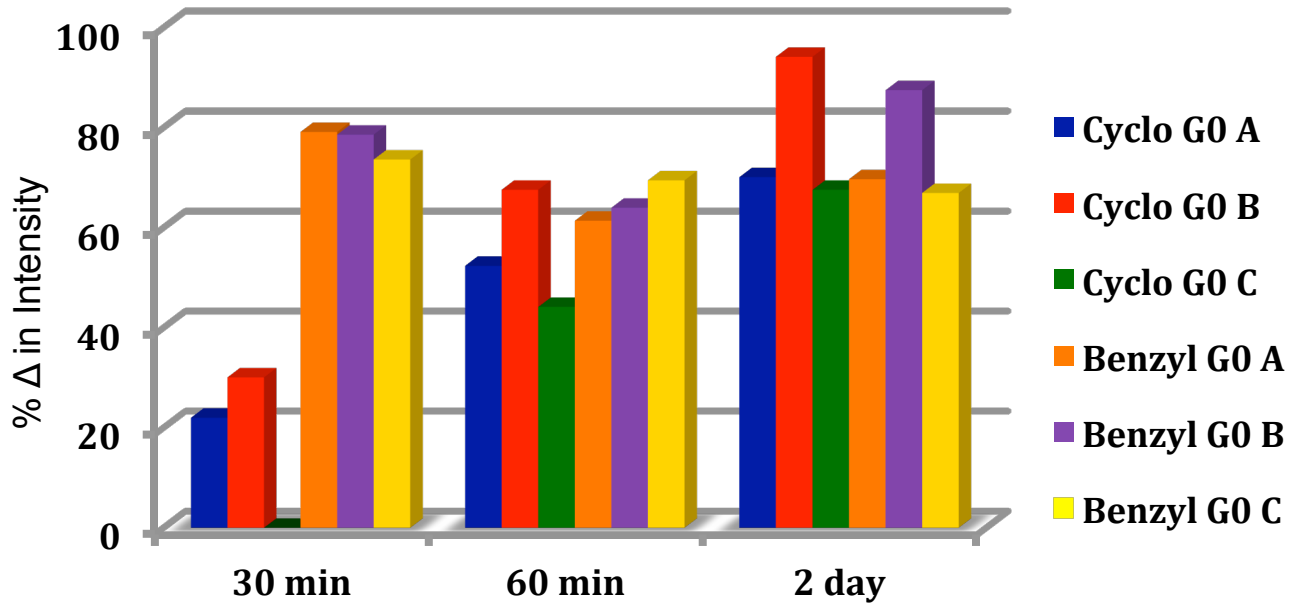


Figure: This graph shows the comparison between cyclohexane and benzyl ether dendrimers.

From this bar graph we can see that the cyclohexane based dendrimers initially at 30 minutes do not have a large percent change in the intensity while the benzyl ether dendrimers do. What is interesting is that after 60 minutes, the cyclohexane based dendrimers catch up with the benzyl ether dendrimers and have a drastic percent change

in the intensity. After two days, all of the dendrimers examined here seem to have a comparable percent change in intensity. From this data, we can see that both the cyclohexane and benzyl ether dendrimers have an effect on the encapsulation of organic pollutants from our water supply. This experimental data shows that dendrimers are in fact reacting with the organic pollutants left behind in our water supply and would be a promising option for a new water purification technique.

One may think why would we want to add another organic compound to our water to purify it, which is a valid question. The uniqueness of dendrimers is that they are completely insoluble in water but have the property of encapsulating organic pollutants from water, releasing the pollutant with a change in pH.[58] Michael Arkas, a leading scientist in dendrimer research notes, "ceramic porous filters can be impregnated with these compounds resulting in hybrid organic/inorganic filter modules."[59] He reports that these filters can remove more than 95% of PAHs and more than 80% of trihalogen methanes, monoaromatic hydrocarbons, and pesticides found in water.[60] Currently, dendrimers are not used on a large scale for water purification. Although they more effectively encapsulate pollutants that are not removed by present techniques, dendrimers are more expensive to make and use. On large scales, companies would prefer to cost effectiveness over efficiency of removing these harmful pollutants. In the future with more research, dendrimers could possibly be utilized but more cost-effective ways need to be deciphered before put into widespread use.

Shift to Bottled Water

[58] Frechet, Jean M. Dendrimers and Other Dendritic Macromolecules page 3715
[59] Arkas, Michael Organic/Inorganic Hybrid Filters page 2771
[60] Arkas, Michael Organic/Inorganic Hybrid Filters page 2771

The Movement Towards Bottled Water. "In our health-conscious society, we're afraid that public fountains, and our tap water in general, are sources of contamination and contagion".[61] It is quite simple to see why many fear tap water and make an uninformed decision that bottled water is the safer option based on the history of water systems and the spread of disease. What many fail to acknowledge is the extensive regulation of public water systems and how harmful pollutants are detected immediately, along with direct public notification. Bottling companies do not abide by the same regulations and are not mandated to release reports of pollutant levels to the public. Instead they focus on contributing to consumer's fears. The water bottling companies make a profit off of a commodity that should cost very little by designing bottles that boost a certain type of style or position in society. "If we can be made to fear our tap water, the market for bottled water skyrockets".[62]

For example, the word "tap" has negative connotations when considered in respect to water. Generally, people prefer "spring" water because of varying images of springs, such as clear blue water flowing freely hidden away in pristine, lush, green woods without human influence. These images lead the consumer to believe that bottled water must taste better and be healthier if coming from such a pure source instead of through pipes underground. On the contrary,

Figure courtesy of
http://www.womansday.com

[61] Gleick, Peter page 3
[62] Gleick, Peter page 6

the definition of "spring water" is not what we traditionally would think. According to the FDA, "water must come from an underground formation from which water flows naturally to the surface of the earth. It may be collected through a borehole, instead of an actual spring."[63] This is a dishonest practice because the bottling company should let consumers know where their water is really coming from and have therefore devalued the water they distribute and sell. Water collection through a borehole is allowed by the FDA when there is a "hydraulic connection between the spring and the borehole," the water must be continuously flowing, and must have the same "physical properties as the water from the spring."[64] There is controversy over boreholes because the pumps can pull from a wider zone that can collect pure water, but also inadequately natural filtered water that could contain contaminants. Since the contaminant regulations are different there is a higher chance for the contaminant to enter the water supply unbeknownst to the consumer.

Case Study: Fryeburg, Maine. Gandhi once said, "There is enough water for human need but not for human greed".[65] Legal battles over large companies taking water from small towns is occurring all over the United States, especially in Fryeburg, Maine over Nestlé's Poland Spring brand. *Tapped* is an important documentary that provides a behind-the-scenes look of the water bottling industry and how it has made water into a commodity that is sold back to the public. By examining the production process of water bottles themselves and where they end up, the documentary exposes the negative impact the large industries have on the communities around their facilities as well as environmental degradation. For example, Eugene Brown, a city council member in Durham, North Carolina

[63] Royte, Elizabeth page 27
[64] Royte, Elizabeth page 28
[65] David, Josh Tapped DVD 2009

noted that during a severe drought, Pepsi continued to pump 400,000 gallons of water a day, disregarding the community's need for water.[66]

Nestle has gained corporate control over drinking water by its sheer size and manipulation of small towns. Nestle had reported 3.6 billion dollars in water sales in 2008, but 35 states suffered from drought in 2007.[67] How could this ethically happen? Nestle controls multiple brands across the United States, such as Poland Spring, Deer Park, Zephyrhills, Ozarka, Ice Mountain, and Arrowhead and strategically gains access to water sources. In Maine, Nestle bought land without resident knowledge. As the water is packaged at the Poland Spring plant, the large corporation is a beneficiary of the source water and therefore pays taxes on the land but withdraws the water for less and ships most of the natural resource out of state.[68] Fryeburg, Maine is a small town that is upset with Nestle and wants to fight for their right to their own water, but small communities in general cannot combat the fancy lawyers and large budgets of these corporations. Another unfortunate dispute in Maine over their water supply is that Maine operates through "absolute dominion" meaning that whoever has the biggest pump can take the most water. To Nestle and other large corporations, water is seen as "blue gold" since the water market is valued at 800 billion dollars.[69]

Environmental Communication: Water Propaganda. Elizabeth Royte, author of *Bottlemania: How Water Went on Sale and Why We Bought It* mentions that consumers did not initially drink bottled water for thirst reasons, but of what it signified. Brands such as

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[66] David, Josh Tapped DVD 2009
[67] David, Josh Tapped DVD 2009
[68] David, Josh Tapped DVD 2009
[69] Ruth Caplan, Defending Water for Life Alliance for Democracy, National Coordinator. Interviewed for *Tapped* Documentary

Perrier, Evian, or Vittel possess a social significance and indicated a higher-class position through consumption. Water became a "social—not just a physical—resource".[70] The irony in this is that as a marketing ploy in 2006, Fiji attempted to discredit the quality of the tap water in Cleveland because of a past water crisis, making a joke by emphasizing that their water is not from Cleveland. The original water-delivery system in Cleveland consisted of one veteran of the War of 1812 carrying two barrels of water on a wagon carried by a pony through town.[71] The city outgrew the veteran's water-delivery system, modernizing to a refined set of reservoirs and pipelines to make water available to residents. The mid-1960s is where the trouble began for Cleveland's reputation for water quality when "untreated municipal and industrial wastes from U.S. and Canadian cities had turned Lake Erie into a dead zone".[72] The poor quality of the water found in Cleveland at the time led to the enactment of federal regulations. Once the Fiji ad surfaced, Cleveland wanted to protect its positive reputation for its changes made to make the water safer by testing water samples of both city and Fiji water for hazardous contaminants. Although both met federal safety standards, the supposed pure bottled water contained "volatile plastic compounds, [and] 40X more bacteria than are found in well-run municipal water systems".[73] The Fiji water

Figure: Fiji's marketing mistake courtesy of http://www.takepart.com

[70] Royte, Elizabeth page 33
[71] Gleick, Peter page 15
[72] Gleick, Peter page 16
[73] Gleick, Peter page 16

sample more importantly contained 6.3 micrograms of arsenic per liter where Cleveland city tap did not contain any arsenic.[74]

Some bottlers also claimed that their water cured various diseases. For example, Poland Spring was said to "cure dyspepsia," also known as indigestion, and "liver complain" but there is no way to prove these claims.[75] The companies can only prove that drinking water, whether it is bottled or tap, flushes impurities from the body and helps to relieve fatigue by keeping the body hydrated. An odd point can also be highlighted here regarding the health aspects of consuming bottled water. Craig Stevens, the Vice President of Communications at the American Beverage Association represents Nestle products, such as Aquafina, Dasani, and Fiji. He asserts that they provide pure water to consumers, yet when the interviewer for *Tapped* mentions bottled water recalls, he says that he has never heard of any. This point is insane because multiple companies have recalled water, such as Coca Cola, Perrier, San Pellegrino, and even Nestle.[76] Even if the water was initially bottled as "pure," the bottles themselves introduce harmful compounds into the water.

The success of bottled water is outrageous because of the astronomical prices of a basic human need which people are willing to pay for. In the United States, "more than 89% of tap water meets or exceeds federal health and safety regulations" and wins blind taste tests against the pricey bottled waters, costing "240-10,000 X less" than bottled water, yet consumers continue to idiotically spend their money on the style of the plastic bottles.[77] Bottling companies market to stir consumer's emotions and have successfully increased bottled water sales. A Brita filter ad uses lines such as "We'd like to clear up a few things

[74] Royte, Elizabeth page 34
[75] Royte, Elizabeth page 32
[76] David, Josh Tapped DVD 2009
[77] Royte, Elizabeth pages 40-41

about tap water" and "You deserve better than the water you mop with".[78] Subliminally equating tap water with dirt, the bottling companies attempt to make their water the "clear" choice for drinking instead of their "competitor". Water brands also question our intelligence with their brand names, such as Smartwater, insinuating that the water we are consuming now (whether it is another brand or tap water) is not the right decision and we should choose something "smart". Smartwater's slogan: "Purity you can taste. Hydration you can feel" leads the consumer to believe that they are missing something substantial from their tap.[79]

Industry constantly refutes the claim that they are in competition with tap water while there have been clear documentation that powerful players have said such a thing. Shortly before Robert S. Morrison became chairman of Pepsi's North American Beverage and Food division, he publicly declared that "the biggest enemy is tap water…we're not against [tap] water—it just has its place. We think its good for irrigation and cooking".[80] Joe Doss, president and CEO of the International Bottled Water Association was interviewed for *Tapped*, a documentary on the water bottling industry. He claimed that he could in fact tell the difference between tap and bottled water. He must have some sort of extremely sensitive palate for this to be the case. Doss also said that tap is not seen as a threat throughout their organization, but there must be a disconnect in his claim. The interviewer brings to his attention that five Pepsi employees have been documented saying that tap is a threat, so where is this divide in information originating? Some in industry try to claim that bottled water is different because its quality is consistent, which implies that tap water is

[78] Gleick, Peter page 10
[79] "8 Bottled Water Brands—Unscrewed" http://www.womansday.com/food-recipes/8-bottled-water-brandsunscrewed-72193
[80] Gleick, Peter page 7

not. There is a gap in the environmental communication and implication of water practices between the EPA and bottling industry moguls, leaving consumers misinformed. Consumers do not know where bottled water comes from, which is problematic since "40% of bottled water is tap water."[81] Brands such as Aquafina and Dasani are deceitful on their labels because they picture landscapes of the mountains and natural settings, tricking the consumer that these water sources are found in nature. Instead, Aquafina and Dasani both have their source water from municipalities or public water sources and not the mountains.[82]

Plastic Water Bottles: The Choice Between Portability and Toxicity. The plastic bottles that are often praised for their portability are made in refineries in PET chemical plants. PET or PETE stands for paraxylene or p-xylene, a clear liquid product from refining crude oil.[83] This chemical is in the benzene family, which is a commonly known carcinogenic agent. The material safety data sheet (MSDS) for PET is alarming, which makes one question why the chemical would be used as a material in bottle production. PET also has some alarming health effects. If ingested, which is likely to occur since chemicals can leach from the bottle into the water, PET can cause "irritation of the digestive tract," "central nervous system depression," "headache, dizziness, drowsiness, and nausea".[84] If these side effects were not serious enough, prolonged exposure can cause "collapse, unconsciousness, coma, and possible death due to respiratory failure".[85] Along with affecting the human digestive and nervous system, PET also negatively impacts the

[81] David, Josh Tapped DVD 2009
[82] David, Josh Tapped DVD 2009
[83] David, Josh Tapped DVD 2009
[84] MSDS section 3-- http://fscimage.fishersci.com/msds/95257.htm
[85] MSDS section 3-- http://fscimage.fishersci.com/msds/95257.htm

environment. This chemical hazardously decomposes to carbon monoxide and carbon dioxide, which are detrimental to our environment and atmosphere.[86] PET can also leach into the soil and seep into our drinking water supply, negatively affecting our tap water as well. Bioassays have also been performed and determined that PET is detrimental to fish and invertebrate health. Why would companies continue to use this chemical that is blatantly not ecologically friendly and also negatively affects the human race?

The "…plastics we discard every year in the millions of tons persist in the environment for hundreds of years."[87] Jennifer Ackerman's article in *Scientific American Magazine* entitled "Plastic Surf: The Unhealthful Afterlife of Toys and Packaging" discusses the horrific problem of plastic garbage floating in the ocean. She notes that plastics do not get digested by microbes as food and paper do, but slowly "photodegrade" through ultraviolet light exposure from the sun.[88] Scientists fear the inclusion of plastic confetti into the marine food web because it will be consumed by larger organisms and in the end consumed by humans. Besides ingestion of plastics by the marine species, the plastic debris also act as magnets or sponges for toxins found in water, such as DDT and dioxins, "absorbing concentrations of one hundred to a million times that of surrounding sea water."[89]

Environmental art is helpful in highlighting the urgency of the regulation of environmental pollution. Chris Jordan has a series of environmental art called *Running the Numbers: An American Self-Portrait,* which focuses on American culture "through the

[86] MSDS section 10--http://fscimage.fishersci.com/msds/95257.htm
[87] Ackerman, Jennifer
[88] Ackerman, Jennifer
[89] Ackerman, Jennifer

austere lens of statistics."[90] Each image when zoomed in is composed of a specific number of an object, such as 2 million plastic beverage bottles, which is the amount used in the United States every five minutes. The artist wishes to stir public awareness with his visual quantification of our waste. Through his art, he wants the public to feel a sense of responsibility of our waste in the overwhelming representation of our consumer culture. Chris Jordan also graphically depicts the implications of plastic debris in our oceans. He photographs the remains of birds that ingested plastic particles on Midway Atoll, a cluster of islands "more than 2000 miles from the nearest continent."[91] The effects of human mass consumption on the baby albatross species appall him. The albatross's parents mistake floating trash for food and feed their babies debris instead of nutritious food. Researchers first began noticing the debris in the ocean in the mid-1960s, but did not recognize its implications until years later. Susan Freinkel, author of *Plastic: A Toxic Love Story,* identifies plastic as a major threat to birds, instead of feather hunters in the past. She recalls seeing

Figure courtesy of www.chrisjordan.com/gallery/midway/#CF000313%2018x24

[90] http://www.chrisjordan.com/gallery/rtn/#about
[91] http://www.chrisjordan.com/gallery/midway/#about

parent birds passing plastic to chicks instead of slurries of squid and fish eggs. "With their stomachs stuffed full of plastic odds and ends, the chicks may not be able to drink, or even recognize that their bodies need food for water."[92]

Further research of these "plastic islands" has been done over the years. Charles Moore shared his research of the North Pacific subtropical gyre in an article for *National History Magazine* in 2003. While racing his boat between Hawaii and California, Moore decided to take a look at the plastic island in the middle of the ocean. He found that the subtropical gyre is created by "mountainous flows of air moving from the tropics toward the polar regions."[93] The winds near the center of the gyres are usually calm, so the debris does not mix or float into the ocean water column, leaving the plastic to accumulate as garbage in the open ocean. Moore estimate that the "weight of the debris was about 3 million tons, comparable to a year's deposition at Puente Hills, Los Angeles's largest landfill."[94] Curtis Ebbesmeyer, the leading expert on flotsam, estimated that the area was roughly the size of Texas.[95] Ebbesmeyer and Moore sampled the gyre together and along with plastic-plankton soup found a drum of hazardous chemicals, plastic coat hangers, an inflated tire, and tangled net lines. After evaluating their research, Moore reported that there are "six pounds of plastic floating in the North Pacific subtropical gyre for every pound of naturally occurring zooplankton."[96] There is no hard data on how long recycling in the ocean takes place, but ecologists have estimated that it could take 500 years or more.

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[92] Freinkel, Susan page 117
[93] Moore, Charles page 5
[94] Moore, Charles page 3
[95] Moore, Charles page 2
[96] Moore, Charles page 7

The debris accumulation is alarming since "40% of the oceans are classified as subtropical gyres" which is one forth of the planet's surface area.[97]

Some people have only switched to drinking bottled water because they are scared of what is in their tap water, but this is not necessarily the healthier option since the consumer may actually be exposing themselves to other harmful compounds. Jane Houlihan, Vice President of research for the Environmental Working Group comments that "companies can keep reports to themselves and not make them available to the public" which is a terrifying thought.[98] Bisphenol A, or BPA, is a chemical compound which has been a recent health concern since it can leach from the bottle and into water. To prove this, Test America and an environmental chemist separately tested seven water bottle brands to determine what compounds migrated into the water from the plastic packaging at room temperature and also examined the water content after temperature fluctuation. Test America found toluene in some of the water samples, which is found in gasoline and paint thinners and is considered a neurotoxic agent.[99] After the water bottles were left in a car for one week, the water samples contained styrene and phthalates, both harmful in reproduction. A PhD chemist and associate director of the National Toxicology Program for the National Institute of Environmental Health Sciences defines BPA as a "high-production industrial chemical used to manufacture polycarbonate plastics and epoxy linings of tin cans."[100] He continues to say that the reason for recent study of this compound is that at low doses from plastic items, BPA can affect hormonal processes. Scientists are concerned about this compound because even small exposure to fetuses, infants, and children could

[97] Moore, Charles page 8
[98] David, Josh Tapped DVD 2009
[99] David, Josh Tapped DVD 2009
[100] BPA report, page 24

cause "neural and behavioral effects, effects on the prostate and mammary gland, and an earlier age at which females attain puberty."[101] There is less of a concern for the risk of BPA for other segments of the population. Scientists based their recommendation to reduce BPA exposure to developing humans through the use of animal studies and scientific literature. There has been concern to the possible health hazards, therefore its "use has been voluntarily stopped or restricted to levels that do not exceed the predicted no effect concentration".[102] Although scientists recommend that BPA should be avoided, the FDA in 2008 did not believe that BPA was a harmful substance at the time. Norris Alderson from the FDA in the Department of Health and Human Services insists that the toxicology studies provide "limited evidence and contain numerous uncertainties" and therefore no reason at that time to change BPA regulation practices.[103] Dr. Alderson tried to appease the public by saying that FDA regulations are never "set in stone" and can change if "better analyses" surface, but the problem here is that people were still consuming low levels of BPA that were already thought to be harmful.[104] If there is even an inkling of possible harm to human reproduction and hormone levels, the compound should be removed from food containers and infant products.

Susan Freinkel, author of *Plastic: A Toxic Love Story* also outlines the plastics we are most likely to encounter. She mentions that polyethylene is in more than one third of all plastics produced and sold worldwide because of their toughness and flexibility. Common products that we see polyethylene used in are shrink-wrap, bottled, beverage cups, and grocery bags. Another chemical, PET is commonly used because of its clarity for packaging.

[101] BPA report, page 24
[102] Patrick, Stuart G PVC Compounds and Processing pages 11-12
[103] BPA report, page 34
[104] BPA report, page 35

PET has a "glasslike clarity" and can provide an airtight space to keep food fresh.[105] The oxygen is kept sufficiently well out of soda bottles so that the fizz-producing carbon dioxide can be kept inside. In *Environmental Health Perspectives* Journal, Yang et al. discuss their laboratory results to evaluate the release of estrogenic chemicals from plastic products. This laboratory used a "roboticized MCF-7 cell proliferation assay," a very sensitive and accurate technique, to quantify the level of estrogenic activity of chemicals leached into solvents from plastic materials. They found that commercially available products including BPA free products leached chemicals with estrogenic activity. This is detrimental to human health according to Yang et al. because estrogen activity can produce health-related problems such as "early puberty in females, reduced sperm counts, altered funcitons of reproductive organs, obesity, altered sex-specific behaviors, and increased rates of some breast, ovarian, testicular, and prostate cancers."[106] They also found that with increased exposure to common-use stresses such as "UV radiation, microwave radiation, and/or moist heat via boiling and dishwashing" causes an increase of leaching of monomers and additives from plastic items.[107] To solve this problem Yang suggests using monomers and additives that are available that do not exhibit estrogenic activity, even when they are stressed. Estrogenic effects of bisphenol A can also be seen in the disruption of pancreatic beta-cell function, which induces insulin resistance. Alonso-Magdalena et al. found that BPA "imitates 17beta-estradiol" which effects the blood glucose homeostatis.[108] She reports that abnormal levels of environmental estrogen can increase the risk of developing types 2 diabetes, hypertension, and dyslipidemia.

[105] Freinkel, Susan page 238
[106] Yang et al. page 989
[107] Yang et al. page 989
[108] Alonso-Magdalena et al. page 106

Creating water bottles not only degrades the environment through the use of harmful chemicals such as PET, but bottle manufacturing also uses 714 million gallons of oil, or 17 million barrels of oil each year.[109] This number includes transporting bottles to bottling plants, distribution centers, and for transportation for final sale. *Tapped* also interviews Elizabeth Royte, author of *Bottlemania,* who comments on how 50 billion bottles are produced yearly, which generates 2.5 tons of carbon dioxide. In a time where scientists are worried about climate change, practices should be changed so that the environmental impact is lessened. An important case study is Flint Hills, an oil refinery in Texas where most PET production occurs. *Tapped* examines the community around Flint Hills and finds that many are dying of cancer, even at young ages because the community was built on top of an oil waste field. These people are the most vulnerable because they are out of sight and out of mind, receiving the brunt of the immediate impact from the oil refinery practices. Melissa Jarell, an assistant professor of criminology at Texas A&M University notes that certain health hazards are more commonly found around oil refineries such as Flint Hills. She has found that there are higher than Texas's average of birth defects in the area surrounding Flint Hills.[110] Many residents moved into the area before the health effects of regarding bottle manufacturing were released and now wish to move out of the area but cannot afford to because of the low value of their homes. People do not want to voluntarily put their health at risk by living in a highly polluted area. The residents would lose the battle against the large oil companies, which is why they choose not to fight for an environmental overhaul of the area.

[109] David, Josh Tapped DVD 2009
[110] David, Josh Tapped DVD 2009

When we do not know the long-term heath effects on human health and the environment, it is idiotic to take chances with your health. The precautionary principle's basic message is that "on some occasions, measures against a possible hazard should be taken even if the available evidence is not sufficient to consider the existence of that hazard as a scientifically established fact."[111] The ethical view here is that we should act to prevent harm in situations even when the threat is uncertain to protect the environment and ourselves. The precautionary principle is general so that it can be applied to a vast array of policies to instate national or international law. We can make a moral argument for the precautionary principle, appealing the public responsibility and accountability of human action. The Rawlsian thought experiment exemplifies this idea by outlining a situation where participants must decide the policies in a society where they do not know their place. The participants acted behind a "veil of ignorance' to choose a principle which maximizes the position of the "least well-off in society."[112] Supporters of the Precautionary Principle argue that because there has been too much faith in scientific evidence some risks have been neglected with the lack of scientific evidence. Science does possess some limitations and with the lack of scientific evidence in some cases, policy makers have failed to consider those limitations when there is an actual threat to health and quality of life.

Conclusion: Balancing the Options

Over the years as more scientific data has been released of the harmful pollutants found in water, action is finally being taken to improve our drinking water quality. Drinking water pollution can be dealt with in three different ways: pollution prevention, filtration and purification, and bottled water. Pollution prevention involves protecting our main

[111] Precautionary Principle page 177
[112] Precautionary Principle page 177

water sources in watersheds with limitations on building practices. This is the most important way to protect and preserve our water quality because we are eliminating pollution at its source instead of the end-of-pipe methods. The introduction of smart growth instead of suburban sprawl also helps to combat further environmental degradation. When we preserve open spaces for natural purification, the quality of water will improve and some pollutants may be naturally filtered out before reaching the groundwater supply. The introduction of pollutants in our water cycle is detrimental to water quality; therefore paved surfaces should be limited so that the chemicals do not run into stormwater and eventually flow into our waterways. If pollution cannot be prevented at the source, the next best option is purification and filtration processes. Pollution that is already present can be purified by filtration and other purification practices, although some pollutants are not removed through these purification processes. Dendrimers could be a viable alternative to carbon filters, reverse osmosis, and distillation processes because they are able to encapsulate organic pollutants that pass through current purification systems. Lastly, we can use bottled water for drinking, but there are still possible health effects from consumption. All three of these policy recommendations are valid on some scale and depending on the circumstances. There could be a mix of all three practices to ensure the best for our health.

From the research collected from scientific journals, books, and documentaries, we can see that bottled water is the last resort for drinking water. Bottled water has wider ecosystem effects than expected. As seen in Chris Jordan's environmental art, the albatross is severely affected by plastic garbage into our environment. Other marine life is also negatively affected because of the disintegration of plastic by ultraviolet light in the ocean.

Making the bottles themselves has a much larger carbon footprint compared to that of tap water. In the Intergovernmental Panel on Climate Change (IPCC) Report, there is a correlation between human impact on the environment and climate change through greenhouse emissions. Climate change caused my emissions from bottling companies also has an effect on our ecosystem services, as seen in the Millennium Ecosystem Assessment. In order to protect ourselves from the harmful effects on the environment from the production of bottled water and leaching of chemicals from the bottles into water, the precautionary principle should be used. We are ethically responsible to protect the environment along with our own health to preserve what nature we have left for future generations. It is not morally just to allow disproportional pollution and consequential negative health effects for those living in closer proximity to factories. Although water bottles may be an easy option for the on-the-go lifestyle, it is imperative that we consider what other environmental effects our seemingly small choices have on the environment and others. That first sip of crisp bottled water may taste refreshing, but is it really all that pure to begin with?

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