Water....I'll Drink To That!

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This research paper traces the earliest simple water purification methods used for the express purpose of improving taste, to the methods used today, in light of health-related issues, and the efficacy of these methods.

ABSTRACT

This science experiment was conducted to learn whether or not river water could be purified for human consumption, using inexpensive and easy procedures. Four liters of water were collected from the Tennessee River and then divided into seven equal portions. Six of the portions were given a unique treatment: gold-filtered, gold-filtered and boiled, treated with Alum and then paper-filtered/gold-filtered, gold-filtered and chlorinated, treated with Chlor-Floc and then paper-filtered/gold-filtered, and finally, carbon-filtered. One of the seven portions was left untreated. The seven portions were then each tested for bacteria, lead, pesticides, total nitrate/nitrite, nitrite, total chlorine, pH balance, and total hardness. Tennessee River water was found to be relatively clean, but still unfit for human consumption if left untreated. Carbon-filtering produced the purest drinking water, although boiling, chlorinating, and treating with Chlor-Floc produced water that is safe for consumption. The expectations of purifying river water through the previously mentioned methods were met; however, carbon-filtering exceeded expectations of the degree of purification.

Because of the necessity of water to life, and because of the potential for water to become contaminated with both poisons and germs, the necessity of purification of water for the health of humanity is imperative to the health of human societies. Sick people make for sick nations. Pure water is central to the health of people. Around the world, impure water spreads disease, sapping the economic vitality of nations; indeed, pure water, far from being a luxury, might best be considered a prerequisite even to the basic functioning of a society. Economic considerations do not even address the moral implications of huge segments of humanity suffering needlessly for want of something that we in the West take for granted. Educating the population of both the great suffering inflicted upon a large portion of humanity from the lack of clean water and the inexpensive and simple solutions that could bring alleviation is the first step in correcting a moral injustice.

The realization that water must be purified for better health is revealed in writings dating as far back as 2000 BC. Writings from the ancient Greeks and Indians describe their methods of purifying their drinking water. As people of those days did not know about micro-organisms or chemical contaminants, their primary purpose in purifying drinking water was simply to improve the taste. The three methods used were straining, sand and gravel filtration, and boiling. Straining removed the larger particles from water, and sand or gravel filtration was used to pull very small particles out of the water. Ancient people also learned that boiling water improved the taste of the water (Enzler, 2011).

There are many different toxic minerals that can be found in water, depending upon the area in which the water system is located. Some toxins are less harmful than others, some are man-made, and some occur naturally. Known minerals in water that are harmful include aluminum, arsenic, asbestos, lead, mercury, copper, silver, barium, nitrate, nitrite, selenium, chromium, cadmium, and fluoride in excess. However, there was no awareness either of the existence of these minerals or of their harmful effects on humans until the last hundred and fifty years (Ingram, 2006). Purification of water did not advance greatly from the time of the ancient Greeks and Indians until the Seventeenth Century when Sir Francis Bacon, a dabbler in scientific research, attempted to use sand filtration to desalinate seawater. His experiments did not work, but his work led to a renewed interest in water purification. Improvements made to lens magnification led to the perfection of the microscope by Antoine van Leeuwenhoek in the 1670s. Through the use of his microscope, van Leeuwenhoek discovered that water contained micro-organisms (Enzler, 2011).

In the 1700s, water filtration was applied to domestic use. After a widespread cholera breakout during the mid-nineteenth century, scientists and physicians noted that populations that had access to filtered water were not affected by the outbreak (Enzler, 2011). A British scientist named John Snow discovered that adding chlorine to water purified the water. This discovery led to governments' installing regulations on public water (Alters, p. 85). The mechanism by which chlorine kills microorganisms is not entirely understood. However, researchers believe that "chlorine, which exists in water, as hypochlorite, or hypochlorous acid, reacts with biomolecules in the bacterial cell to destroy the organism" (Calomiris & Christman, 1998, p. 1). The chlorine destroys the permeability of the outer membrane. "But the means by which chlorine inactivates viruses is not well understood" (Calomiris & Christman, 1998, p. 2). However, the results have been extraordinary. Health officials in the United States, for instance, discovered that typhoid fever, which killed approximately 25 out of 100,000 US citizens each year, was almost entirely eliminated in areas of the country where water was chlorinated (Calomiris & Christman, 1998, p. 1). However, while chlorination provided many benefits, it was also discovered that excess chlorine led to respiratory problems. Furthermore, chlorine evaporates more quickly than water. The addition of chlorine to water presented the challenge of balance. Scientists had to determine the correct proportion of chlorine to water in order to have the desired effect (Enzler, 2011).

Although water treatment plants have been in use for nearly 150 years, there are many nations in which zero percent of its citizens have access to safe drinking water accounts for nearly 1.1 billion human beings, or more than one-seventh of the human population ("Scoring," 2010). In addition to this crisis, nearly 2.6 billion people lack proper sanitary facilities. The lack of access to pure water leads to 1.8 million deaths per year due to diarrheal diseases ("Water Supply and Sanitation," 2010). The germs most common in causes of intestinal upset are Cryptosporidium parvum and Giardia lamblia. These germs cannot survive in water for very long, but if consumed while alive, they can cause intestinal upset or even death. Unfortunately, even chlorine cannot kill these germs. The water must be boiled or treated with stronger disinfectants (Lerner & Lerner, p. 623). Ninety percent of deaths due to unclean water are very young children. The majority of the countries with the least access to pure water are located in Africa, followed by the Middle East and Asia ("Scoring," 2010).

The United States ranks among the top of nations that provide safe drinking water to their citizens. Ninety-eight percent of all Americans have access to clean drinking water. This leaves over 5.1 million Americans without access to safe drinking water ("Scoring," 2010). Fortunately for these Americans, there are methods that can easily, inexpensively, and quickly be used to purify water. In fact, all Americans would do well to acquire the means and the knowledge to purify water for three reasons. One is that water treatment plants rely on fuel to operate, whether to produce electricity or to run a generator. Without power, treatment plants cannot continue to purify water. The likelihood of this might be rare, but a natural disaster of great magnitude could easily affect the operations of a treatment plant. Another reason to take precautionary methods is the rise of terrorist activity throughout the world. In addition to the need to be able to purify water due to natural or human disasters, a third reason reflects the original purpose of purifying, which is simply to improve the taste. According to Jim Reynolds, who directs the Water Quality Lab at the South Parkway Water Treatment Plant in Huntsville, Alabama, water does not leave the plant until it is proven to be safe and "passes the taste inspection by the chief plant operator" (personal communication, October 12, 2011). Therefore, Huntsville depends upon the personal taste of the plant operator.

Individuals can use many of the steps taken by water treatment plants to purify their own water. The purification methods used in most places around the world come down to six basic steps: screening, aeration, flash mixing, flocculation/coagulation, filtration, and disinfection. During screening, large contaminants such as plant matter, wood, pebbles, and fish are removed. Some treatment plants follow screening with aeration. Aeration is simply sending screened water into aeration tanks which inject large amounts of air into the water. Aeration helps to reduce adverse tastes and odors. Flash mixing is adding chemicals into raw water for the purpose of neutralizing certain impurities. In water high in calcium and magnesium, for example, a mixture of lime and sodium carbonate is usually added. Chlorine is also added at a fairly high strength. As chlorine will evaporate faster than water, chemists can count on ensuring a safe adjustment in chlorine levels before the water is cleared for delivery to the general public ("Water Purification," 2005).

The next step in water purification is coagulation and flocculation. This step addresses the minute solids suspended in water called colloids. Colloids are present in all raw water and can include salts, acids from decomposed animal and vegetable matter, bacteria, plankton, algae, viruses, and many other micro-organisms. A colloid is a substance that remains dispersed due to its negative electric charges. As these particles repel each other, it is extremely difficult to collect them. Because of their extremely small masses, they do not settle to the bottom of a holding tank. They continue to float on or near the water surface. As these colloids have a negative charge that repels them from each other, a cationic chemical is added to the water. Cationic flocculants have positive charges. The addition of a cationic chemical neutralizes the negative charges of the colloids ("Drinking Water," n.d.). Natural flocculants include corn and potato starches and polysaccharides such as guar gum ("Flocculants.info," 2007). A common chemical used in flocculation is Aluminum potassium sulfate, also called "potash alum", or simply, "alum." Flocculation requires both chemical and physical procedures. After a neutralizing chemical is added to water, the water must be physically agitated in order to allow the chemical to come into contact with the colloids. When colloids are neutralized through the chemical reaction, they collide with each other, forming larger particles ("About Coagulation," 2009). These larger, neutralized particles are called "flocs" ("Water Purification," 2005).

The next step in water purification is filtration. Once the tiny particles are flocculated and they coagulate into the desired size, they can be removed through filtration ("About Coagulation," 2009). Water treatment plants also use the ancient method of sand filtration. Water is forced down through a sand bed where additional minute particles which escaped flocculation will adhere to the grains of sand ("Water Purification," 2005).

Finally, additional chemicals are often added to the treated water. These include chlorine and fluoride. Chlorine is used to prevent any growth of micro-organisms in the water once it leaves the plant ("Water Purification," 2005). Fluoride is added to water that does not naturally contain this element, to reduce tooth decay. In areas where there is a high concentration of fluoride in the water systems, fluoride must be reduced to safe levels ("The Story of Fluoridation," 2011).

Understanding how major water treatment plants work will help the average citizen better understand how to purify water if the need should arise. Amazingly, the individual can repeat all of the steps used by water treatment plants plus one more step, boiling, which most believe is the best way to purify water. The usual six steps in purifying water are as follows: straining, aeration, flash mixing, flocculation/coagulation, filtration, and disinfection. When in need of purifying a relatively small vessel of water, all of these methods can be performed with little cost and equipment to the individual ("Purifying Household Water," 2009).

Straining, the removal of large contaminants, can be achieved through the use of a sieve, coffee filter, or cheese cloth. Simply allow raw water to filter through one of these items into a clean vessel. This should be repeated several times using a clean filter and a clean vessel in which to collect the water ("Purifying Household Water," 2009).

Aeration, which is the method of pumping air into the water, can be performed by shaking the water vessel or stirring the water vigorously. Aeration will help to remove odors from the water ("Purifying Household Water," 2009).

Flash mixing requires the addition of chemicals for decontaminating the water. Chlorine is one of two primary choices for treating water. Household bleach is acceptable for use in purifying water as long as it does not contain added chemicals such as perfumes and dyes. Most household bleaches contain five to six percent liquid chlorine bleach. This strength of chlorine requires a very small amount of bleach for water purification. For example, ten gallons of cloudy water can be purified with just one teaspoon of bleach. The chlorine bleach solution should be mixed thoroughly throughout the raw water and be allowed to sit for thirty to sixty minutes, depending upon the cloudiness of the water ("Purifying Household Water," 2009).

Flocculation/coagulation might seem impossible to the average citizen; however, this, too, can be done at very little cost. Aluminum potassium sulfate, better known as potash alum, can be purchased at reasonable prices through the internet, or even from the spice rack at a grocery store, sold as "alum." Potash alum will cause flocculation and the coagulation of colloids in the water. Once coagulation has taken place, the water must then be re-strained in order to remove the coagulants ("Purifying Household Water," 2009).

For an extra step in removing any remaining colloids, the water can be poured through a sand filter. If designing a sand filter is not a project the individual deems reasonable, another filter, such as a coffee filter, may be used ("Purifying Household Water," 2009).

Finally, a highly respected purifying or disinfecting treatment is to boil the water. Boiling water, although not a practical option for water treatment plants, is a very practical choice for individuals with rather small amounts of water to purify. In fact, it is considered the most effective way to purify water. Bringing water to a boil for one minute is sufficient for killing contaminants ("Purifying Household Water," 2009).

With the use of inexpensive supplies and simple methods, many of the world's human population could greatly improve the purity of the water used for drinking, cooking, and basic hygiene. Certainly, for want of minimal materials and knowledge, vast numbers of humanity suffer greatly. It stands to follow that basic improvements made to water would lead to a reduction in suffering and the tragic loss of human life.

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Project Procedure

1. Collect, in a clean container, two liters of Tennessee River water.
2. Sterilize nine containers and seven lids. Each container must be large enough to hold roughly 286 ml.
3. Label the first container "Untreated", pour 286 ml of water into this container, seal with a lid, and set aside. This container will not be given any chemical or physical treatments.
4. Sterilize a gold filter.
5. Label the second container, "Gold-filtered." Place a gold filter above this container and pour in 286 ml of the river water through the filter and into the container. Filtering is the only treatment this water will receive. Seal with a lid and set aside.
6. Sterilize the gold filter.
7. Label the third container, "Gold-filtered/Boiled." Place the gold filter above a sterilized pot and pour in 286 ml of the river water through the filter and into the pot. Place the pot on a stove and bring the water to a boil. Allow the water to boil for three minutes and then remove from heat and cover with a sterilized lid. When the water cools, pour the water into the third container, seal it with a lid, and set aside.
8. Sterilize the gold filter.
9. This next step will require two containers. Label the fourth container, "Alum/Paper and Gold-filtered" and set aside. Take a fifth container and pour 286 ml of the river water into it. Add 1 gram of Alum into the water, stir vigorously for 20 seconds and set aside for twenty minutes. Take the fourth labeled container and place the gold filter above it. Place a paper coffee filter inside the gold filter. When twenty minutes are completed, pour the Alum-treated water into the paper/gold filters and into the labeled container. When the Alum treated water is completely filtered into the labeled container, seal with a lid and set aside.
10. Sterilize the gold filter and discard the paper filter used in step #9.
11. Label the sixth container "Gold-filtered and Chlorinated." Place the gold filter above the sixth container and pour 286 ml of the river water into it. Add one drop of unscented chlorine bleach to the water. Using a clean utensil, stir the water for ten seconds. Seal with a lid and set aside for twenty minutes.
12. Sterilize the gold filter.
13. This step will require two containers. Label the seventh container "Chlor-Floc /Paper and Gold-filtered." ("Chlor-Floc," the brand name, is used by the United States military as a provision given to military persons who are in situations that don't provide them with access to purified drinking water. It can be purchased at a low cost over the internet or at military supply stores.) Take an eighth container and pour 286 ml of the river water into it. Add one packet of Chlor-Floc to the water, stir vigorously for one minute, set aside for three minutes, swirl for 30 seconds, and then set aside for 15 minutes. When fifteen minutes are completed, place the

gold filter above the labeled seventh container. Place a paper coffee paper inside the gold filter. Pour the Chlor-Floc treated water into the double filter to collect the water in the seventh container. Seal this container with a lid and set aside.

14. Label the ninth container, "Carbon-Filtered." Obtain a water-purifying container with a carbon filter (such as Brita). Follow the instructions of the carbon filter container, using 286 ml of the river water. When the water has finished running through the carbon filter, pour the water into the ninth container, seal with a lid, and set aside.

15. Take the first container labeled "Untreated" and remove lid. A Watersafe Test Kit, will provide all testing materials needed for testing 8 common contaminants for up to 10 samples of water. These include detecting bacteria, lead, the two most common pesticides used in the US (atrazine and simazine), total nitrate/nitrite, nitrite, total chlorine, pH, and total hardness. Follow the Watersafe Test Kit instructions for each test and for interpreting the results. Record the test results in a notebook.

16. Repeat step #15 for the remaining six labeled containers.

17. When all the samples have been tested, data may be compiled, compared, and evaluated.

18. Thoroughly sterilize all containers, the gold filter, and surfaces used in the experiment. The river water may be discarded or kept for visual comparisons.

Testing Results:

Tennessee River Water: Untreated		
pH	8.5	Within Desired Values: 6.5 - 8.5
Hardness	120	Outside Desired Values: 50 ppm or less
Chlorine	0	Within Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0.5	Within Desired Values: Below 10.0 ppm
Nitrite	0	Within Desired Values: Below 1.0 ppm
Lead	Negative	Within Desired Values: Below 15 ppb
Pesticide	Positive	Outside Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	Positive	Outside Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Tennessee River Water: Gold-filtered		
pH	8.5	Within Desired Values: 6.5 - 8.5
Hardness	120	Outside Desired Values: 50 ppm or less
Chlorine	0	Within Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0.5	Within Desired Values: Below 10.0 ppm
Nitrite	0	Within Desired Values: Below 1.0 ppm
Lead	Negative	Within Desired Values: Below 15 ppb
Pesticide	Positive	Outside Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	Positive	Outside Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Tennessee River Water: Gold-filtered and Boiled		
pH	10	Outside Desired Values: Below 6.5 or Above 8.5
Hardness	120	Outside Desired Values: 50 ppm or Less
Chlorine	0	Within Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0.5	Within Desired Values: Below 10.0 ppm
Nitrite	0	Within Desired Values: Below 1.0 ppm
Lead	negative	Within Desired Values: Below 15 ppb
Pesticide	positive	Outside Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	negative	Within Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Tennessee River Water: Treated with Alum/Paper & Gold-filtered		
pH	6.0	Outside Desired Values: Below 6.5 or Above 8.5
Hardness	120	Outside Desired Values: 50 ppm or less
Chlorine	0	Within Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0.5	Within Desired Values: Below 10.0 ppm
Nitrite	0	Within Desired Values: Below 1.0 ppm
Lead	negative	Within Desired Values: Below 15 ppb
Pesticide	Test ran twice, no results	Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	negative	Within Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Tennessee River Water: Gold Filter Chlorine		
pH	8.5	Within Desired Values: 6.5 - 8.5
Hardness	120	Outside Desired Values: 50 ppm or less
Chlorine	10	Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0.5	Desired Values: Below 10.0 ppm
Nitrite	0	Desired Values: Below 1.0 ppm
Lead	negative	Desired Values: Below 15 ppb
Pesticide	positive	Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	negative	Within Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Tennessee River Water: Chlor - Floc/Gold		
pH	6.0	Outside Desired Values: 6.5 - 8.5
Hardness	120	Outside Desired Values: 50 ppm or less
Chlorine	10	Outside Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0.5	Within Desired Values: Below 10.0 ppm
Nitrite	0	Within Desired Values: Below 1.0 ppm
Lead	negative	Within Desired Values: Below 15 ppb
Pesticide	negative	Within Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	negative	Within Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Tennessee River Water: Carbon Filter		
pH	7.5	Within Desired Values: 6.5 - 8.5
Hardness	0	Within Desired Values: 50 ppm or less
Chlorine	0	Within Desired Values: Below 4 ppm
Total Nitrate/Nitrite	0	Within Desired Values: Below 10.0 ppm
Nitrite	0	Within Desired Values: Below 1.0 ppm
Lead	Negative	Within Desired Values: Below 15 ppb
Pesticide	Negative	Within Desired Values: Below 3 ppb atrazine, Below 4 ppb simazine
Bacteria	negative	Within Desired Value: None (negative)
ppm = parts per million units		
ppb = parts per billion units		

Analysis

This experiment proves that water can be easily and inexpensively purified for human consumption. The experiment also shows that despite the appearance of water, unseen contaminants could still be found in the water. The Tennessee River water has a clean appearance and is considered to be one of the cleanest of the major rivers in the United States. No lead is found in the raw water, and the pH balance, the total Nitrate/Nitrite, Nitrite, and Chlorine levels are well within acceptable ranges. However, bacteria and unacceptable levels of pesticides, including atrazine and simazine, were found in the untreated and simple-filtrated waters. The controlled variable, the raw river water and filtered water, looks just as clean to the human eye as the water which was purified through a carbon filter, boiling, or chlorination. However, test results proved that purity cannot be determined by the human eye. The water must be treated to remove harmful bacteria and pesticides. Although the results were not identical, boiling, chlorinating, and carbon-filtering water are three efficient means for removing bacteria. Chlorination and boiling removed traces of bacteria, but did not remove the traces of atrazine and simazine pesticides, nor did these treatments place "hardness" within the desired value for drinking water. Carbon-filtering produced excellent results, however. After carbon-filtering, all tests, which tested outside the desired values on the raw water, fell within range on the carbon-filtered water. This includes the removal of harmful pesticides. Therefore, this experiment concludes that carbon-filtering produces the best results.