“The Value of Water”

To the citizens of Willis, Texas

This paper was written by our Director of Public Works, Arthur Faiello, when he was a student at Western International University in Phoenix, Arizona. This is an excellent report on the subject of water, how we use it, and how we abuse it. I encourage all of our citizens to take the time to read it.

Jim McAlister

City Manager

Abstract

It is universally understood water is the reason all life on Earth exists. However, our natural water cycle and our effects upon it go largely misunderstood and worse yet, few seem interested. This is a glance at Earth's natural water cycle, our uses of water and the effects they are having, the need for human intervention, and one example of the clean-up efforts we are making to mitigate the damage we've already done and prevent further water quality degradation.

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Water: Our Garbage Can

II. Water: Our Finite Source of Life

As indicated by the title, humans have managed to introduce just about every toxic chemical and refuse debris known to man into our water systems. This pollution continues because of, and is compounded by, ignorance; ignorance of how our water systems actually work. For example, most people incorrectly believe we receive new water every time it rains. If that were the case, this planet would be nothing more than a water generator and as such would be one large ocean with no surface landmasses. The fact is there are only 326 trillion gallons of water on Earth (Davis, 2005), and every single gallon of that water was here when Earth was formed some four and a half billion years ago (Sherlock, 1997). Every form of life that has ever existed on this planet has used this same water.

Even though it may seem 326 trillion gallons of water is a more than sufficient supply for all to share, upon further investigation it is evident this supply is not near enough without some means of cleansing it for reuse. This is so because “97 percent of all water on our planet is salt water. Just 3 percent takes the form of fresh water, and 80 percent of that number is more or less frozen away forever in the polar ice caps and in glaciers. That leaves less than 1 percent of all of the water on Earth for people to use” (Davis, 2005).

Given that only 0.6 percent or 1.956 trillion gallons of the water on Earth is available for people to use, it is easy to determine Earth’s water quality would suffer tremendously without the natural *hydrologic cycle* that exists (Davis, 2005). The hydrologic cycle is “the biogeochemical cycle that collects, purifies, and distributes the Earth’s fixed supply of water from the environment to living organisms and then back to the environment” (Miller, 2004, p. G7). See tables 2.1 and 2.2 for a comparison of what Earth's current and projected water turnover rates would be with and without the natural hydrologic cycle:

A. Table 2.1 – Water Turnover Rate Without Current Hydrologic Cycle

Earth's Current Population	**Average Gals. /Day/Person**	**Total Gallons Used Daily**	**Usable Water (0.6% of 326 trillion gallons)**	**Usable Water Turnover Rate**
6.2 billion (Miller, 2004)	50 (Davis, 2005)	310 billion	1.956 trillion	6.31 days
Conservative Population Projection for Year 2100	**Average Gals. /Day/Person**	**Total Gallons Used Daily**	**Usable Water (0.6% of 326 trillion gallons)**	**Usable Water Turnover Rate**
10.5 billion	50	525 billion	1.956 trillion	3.73 days

Given the information in Table 2.1, we can easily determine all usable water on this planet would have been lethally toxic and resembled muddy swamp water long ago if not for the Earth's natural hydrologic cycle.

The information provided in Table 2.1 depends greatly upon the fact everyone on the planet uses an average of 50 gallons of water per day. On average, this is true for developed countries but not necessarily for developing countries. However, large quantitiy users such as industry, etc. likely offset this difference in water use. Obviously, this chart makes some additional assumptions that are currently unknowns such as projected population. However, it profoundly points out the absolute necessity for our natural hydrologic system and for the ability to clean the water we've used so it can be safely reused.

Table 2.1 indicates the usable water turnover rate is currently at 6.31 days, however, this does not take into account the fact a much greater volume of the water on Earth circulates through the usable water supply via the hydrologic cycle as previously explained. Given that 97 percent of all water on Earth is salt water, we can extrapolate that of the 326 trillion gallons of water on the planet, approximately 318 trillion gallons plays an active role in the water cycle, with the remaining 8 trillion gallons tied up in glaciers and ice caps. That being the case, a more accurate and realistic usable water turnover rate is indicated in table 2.2. Notice the dramatic difference in turnover rate our natural hydrologic cycle makes:

B. Table 2.2 – Current Water Turnover Rate With Hydrologic Cycle

Earth's Current Population	**Average Gals. /Day/Person**	**Total Gallons Used Daily**	**Usable Water (0.6% of 326 trillion gallons)**	**Usable Water Turnover Rate**
6.2 billion (Miller, 2004)	50 (Davis, 2005)	310 billion	318 trillion	1025.8 days
Conservative Population Projection for Year 2100	**Average Gals. /Day/Person Used**	**Total Gallons Used**	**Water Volume in Cycle**	**Usable Water Turnover Rate**
10.5 billion	50 (Davis, 2005)	525 billion	318 trillion	605.7 days

As shown, we are currently turning our usable water supply over at a rate of once every 2.8 years rather than once every 6.31 days and by the year 2100 will likely be turning it over once every 1.67 years rather than once every 3.73 days as previously illustrated in table 2.1.

Even with the determination of a current planetary usable water turnover rate of 2.8 years, in the grand scheme of things this is a relatively short period of time. Having this information makes it much easier to understand how easily and quickly we can contaminate all of our planet's water. This demonstrates the absolute necessity for conscientious water use and for wastewater treatment prior to returning the water to the environment.

III. How We Contaminate our Natural Life Force

Given that we are damned to re-use this finite water supply, turnover rate becomes critical. Once it is understood we are contaminating the water with each and every use we can easily see that without proper cleansing between uses the contaminant levels would simply concentrate with every use. We can no longer expect the natural hydrologic cycle to adequately clean the waters of the Earth because our population centers have exceeded our planet's natural carrying capacity, or ability to filter and cleanse the waters for us. Enter the advent of synthetic water treatment facilities.

Most people are content with ignorance when it comes to wastewater treatment. The predominant attitude is: *as long as the waste goes away when the toilet is flushed, or when the sink, tub, or shower is drained, or when the dishwasher and clothes washing machines drain, everything is good.* Very few people actually stop to think about where the waste goes and that someone is out there dealing with this waste so it does not make its way into the environment and pollute our drinking water supplies with pathogenic, or disease-causing organisms (Miller, 2004, p. 236).

To understand how our wastewater influences our drinking water, it is imperative that one has a basic understanding of the Earth's hydrologic cycle. When water is dumped on the ground, a portion of that water evaporates into the air accumulating as moisture until it eventually returns to the Earth's surface in the form of precipitation. The remainder percolates down into the Earth carrying with it any pollutants it may contain. It passes through various layers of soil, sand, silt, rock, and clay. Under normal circumstances, these layers of natural filtering media are sufficient to remove any contaminants before the water reaches the aquifer, or natural underground water channel.

However, once these contaminants are concentrated and the water use volume increases, such is the case with industrial wastes and in highly populated areas, the natural layers of filtration are no longer sufficient to complete the necessary level of contaminant removal. The result is contaminants reaching the aquifer rendering it unsafe for use without treatment. Polluted waters dumped directly into receiving waters have this same effect on downstream users and aquatic life (Miller, 2004, pp.82-83). This is critical because groundwater, or water existing beneath the Earth's surface in confined or unconfined aquifers which we use for drinking and other uses, is pumped via wells from aquifers that are heavily influenced by contaminants breaking through the natural layers of filtration in the earth (Water and Sewer, n.d.).

IV. The Synthesized Cleansing Process

In the interest of maintaining a manageable topic, this focus will remain on domestic wastewater treatment. We generate wastes in many different ways in our homes and in our industries. Although not intended to be a comprehensive list, the following are some ways in which we all pollute our water supply:

1. We use water to carry away our bodily waste such as urine, blood, and other bodily excretions, known as "black water."
2. We use water to wash things such as our bodies, hands and hair, dishes, laundry, household cleaning, etc., known as "gray water."
3. We introduce pesticides, fats, oils, and greases to water supplies by washing foods such as vegetables, meats, dumping unused solutions on the ground or in storm sewers, etc. and by using garbage disposals to send waste products down the drain instead disposing of them in refuse containers.
4. We introduce pharmaceuticals to water supplies with our bodily waste excretions and unused medications that are dumped down drains and flushed down toilets.
5. We contaminate water supplies with aqueous fertilizers for plants, etc., and through landscape irrigation.

For those of us living in an area that is serviced by a municipal wastewater treatment plant, also known as a Publicly Owned Treatment Works (POTW), all of the black and gray water leaving our homes goes down it's respective drain and into a common sewer line that eventually leads back to the POTW through a system of sewer lines and pumping stations known as a collections or sewer system. This wastewater consists of everything that everyone has put down the drain plus any additional flows received through *infiltration*, or foreign flow introduced into the sewer by cracked pipes, pipe joints, manhole rings, and illegal connections, etc. (Water and Sewer, n.d.).

Once the contaminated water, or raw sewage, has reached the POTW, the operations staff has the following challenges to meet in order to return the water to a quality acceptable by federal, state, and local regulations to be discharged back into the environment:

1. Large solids removal
2. Grit removal
3. Biochemical Oxygen Demand (BOD) removal (oxygen used by microorganisms and decaying organic material)
4. Nutrient (Nitrogen, Phosphorous, etc.) removal
5. Particulate solids removal
6. Disinfection and disposal

The first challenge, large solids removal, is met by screening the raw sewage to remove the gross solids such as paper products, rags, etc. Then, to meet the second challenge, the screened sewage is put through one variation or another of grit removal system to remove small rocks, gravel, egg shells, etc. so these constituents do not cause premature wear on plant equipment and eventually reduce treatment capacity by collecting in treatment tanks through settling. Once the grit has been removed, the sewage is then treated to remove BOD and nutrients.

Meeting the third and fourth challenges is much more involved. Although not representative of all systems, the majority of domestic POTW's use the *Activated Sludge Process* to remove BOD and nutrients. The Activated Sludge Process is "a biomass produced in raw or settled wastewater by the growth of organisms in aeration tanks in the presence of dissolved oxygen. The term 'activated' comes from the fact the particles are teeming with bacteria, and protozoa…a process in which a mixture of sewage and activated sludge is agitated and aerated" (activatedsludge.info, n.d.).

Basically, the raw sewage coming into the plant, also known as influent, is very high in BOD and Ammonia Nitrogen. It is undesirable to discharge water, also known as effluent, which is high in BOD or Nitrogen because it causes septic conditions and algae blooms in the receiving waters. These algae blooms, septic conditions, and high Nitrogen contents deplete the receiving water's oxygen content, which kills aquatic life and causes disease in humans and animals. For these reasons, the BOD and Nitrogen are removed through one of several methods using concentrated sewage and activated sludge, known as mixed liquor, along with the presence and lack of dissolved oxygen in various stages of treatment to facilitate removal of these constituents through various different microorganisms, (activatedsludge.info, n.d.).

Finally, the fifth and sixth challenges are addressed. After BOD and nutrient removal, the mixed liquor solids are separated from the water. This is usually accomplished through settling basins but can be done through micro filtration or other methods. Once the water is separated from the solids, it is then filtered to remove any fine particulates. After filtering is accomplished, the water is then disinfected with chlorine, ultra-violet light, or ozone. If chlorine was used, typically it must then go through a dechlorination process before discharge; if not, then direct discharge usually follows disinfection.

V. Responsibly Returning Used Water to Our Environment

There are several accepted methods for effluent disposal. The first of which is direct return to an existing body of water, such as an ocean, lake, river, wash, or stream. This is termed discharging to receiving waters and is regulated by the federal government through permits called National Pollutant Discharge Elimination System (NPDES) permits, which were established in 1973 through the Clean Water Act of 1972, (U.S. E.P.A., 2004). These permits mandate the minimum levels of treatment that must be met prior to discharge as well as maximum discharge volumes, etc.

Another method for effluent disposal is direct aquifer recharge. This is accomplished in many different ways. There are rapid infiltration basins, which are basically large open-air, earthen basins that are discharged to for set periods of time during which the water percolates down through the various layers of soil, sand, silt, etc. and eventually reaches the aquifer thereby recharging it. There are also systems known as injection, or vadose, wells. These are wells whereby the effluent is pumped deep into the ground and then percolates the rest of the way down to the aquifer. And finally, there are systems known as recharge trenches that are nothing more than underground trenches designed to temporarily hold the effluent while it is percolating.

All of the methods for aquifer recharge are regulated by governmental regulatory agency issued Aquifer Protection Program permits (APP). Much like the NPDES permit mentioned earlier, the APP permits mandate minimum acceptable treatment levels, maximum discharge volumes, etc. In some cases, these permits dictate treatment processes and discharge schedules. Any entity or person regulated by one of these permits is under strict requirements to prove they are in fact meeting the permit(s) discharge requirements.

Finally, in newly developed and developing areas, treatment plant effluent is used to conserve potable, (drinking), water supplies. This is accomplished by using the effluent for irrigation of golf courses and common green areas such as road medians, parks, etc., instead of depleting valuable finite potable water supplies for tasks that don't require it. The effluent, or re-use water is also used in the construction process for dust control, soil settling and compaction, and equipment clean up. Because this water does end up on the ground and eventually percolates down to the aquifer(s) it is also regulated by APP permits, and likely Re-Use permits as well.

VI. Playing an Active Role in Reaching Sustainability

It is clearly evident that ignorance of our hydrologic cycle and water treatment processes are large players in the game that is contaminating our water supply. We must all actively strive to increase our understanding of water systems, both natural and man-made. It is also clearly evident our intervention in the hydrologic cycle is making a difference. We are cleaning up a great deal of the disasters we have caused but we have a long way to go before we can say we have attained a sustainable level of water use.

Conscientious water conservation and water use efforts must not only continue, but also proliferate. So, next time you use the water, in any context, stop for a moment and think about how that water got to you, what condition it will be in when your done using it, how you'll dispose of it, and what, if any, treatment will be done to return it to a useable condition prior to re-entry into our environment. Make an opportunity to visit a water and wastewater treatment facility to increase your understanding of the astounding efforts being made daily to ensure a continuous safe water supply for us all, not only now but in the future as well. Our lives, the lives of our children, grand children, and their offspring are depending on it.

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