Academic Journal of Environment & Earth Science
ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

Comparative Study of Conventional and Biological Water Treatment

Shuhan Zhao

Irvine High School, Irvine, CA, USA, 92604

Abstract: *Water is a scarce source. The total amount of water on Earth is about 1.4 billion cubic kilometers, in which 97.2% are oceans. However, the total amount of freshwater resources only accounts for about 2.5% of the total water resources. Of all the freshwater, about 70 percent is locked up in the ice and permanent snow in the mountain, which cannot be used. Approximately 30% of the world's freshwater resources are stored underground in the form of groundwater. 97% of all potentially available freshwater resources for humans are either locked up in the ice and permanent snow in mountains or stored underground in the form of groundwater, including shallow and deep groundwater basins up to 2,000 meters deep, soil moisture, swamp water, and permafrost. Lastly, only about 0.3% of the world's freshwater resource are freshwater lakes and rivers that are accessible and safe to drink for human[1].Given these limited amounts of usable freshwater, approximately 2 billion individuals globally lack access to clean drinking water, as highlighted in the SDG Report of 2022[2]. Additionally, nearly 50% of the global population faces significant water scarcity during certain periods annually[3]. This issue can worsen due to the effects of both climate change and population expansion.Also, because of human-induced contaminations and destructions, drinkable water is facing more damages and negatively affecting both human and animal health. According to a recent study conducted by Orb Media, the environmental scientists present a worldwide investigation of 159 tap water samples from six diverse regions spanning five continents. Among those samples studied, an overwhelming 83% were discovered to contain plastic particles, with the majority of the their lengths ranging from 0.1 to 5 mm, so tiny to be noticed when drinking[4]. These plastics does not only impact humans, but also animal species. It is estimated that 90% of seabirds eat plastics, and plastics can rupture organs of animals, such as fish and turtles, leading to poisoning and starvation[5].Water is highly a vital source of survival, both for human beings and for living organisms. When water pollution increases, it means that these creatures have less water to consume, not meeting their water demands, and they are pushed to the edge of life and death, and may even start competing for water. As human, and as a part of these living things, it is important to find ways to mitigate freshwater scarcity.*

Keywords: *water treatment; convention processes; organic processes; cases; suggestions*

1. Introduction

In light of these alarming trends, this essay aims to identify ways that can filter and recycle the water with leading-edge sustainable urban technologies and practices and at the same time, removing hazardous elements like chlorine, disinfection byproducts, and heavy metals such as mercury, lead, and arsenic from the water.

2. Treatment process

Treating wastewater is crucial to safeguard human well-being and maintain the ecological balance of the Earth. Usually, there are two types water treatment, convention processes and organic processes.

ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

2.1. Conventional treatments

2.1.1. Coagulation/Flocculation

Coagulation and flocculation are usually the first step of conventional water treatment. During this process, it combines chemicals with other substances present in water. These chemicals, usually iron or aluminum salts, like aluminum sulphate, ferric sulphate, ferric chloride, or polymers, known as coagulants, possess a positive electrical charge. This positive charge of the coagulant counteracts the negative charge carried by particles that are dissolved or suspended in the water. As a result, it can form larger particles, called flocs[6].

2.1.2. Sedimentation

This is a method to. As the floc has larger density, it moves downward and accumulates at the bottom of the water treatment tank through sedimentation, forming a removable layer.

2.1.3. Filtration

After the flocs sink to the water bottom, the clean water above is filtered to remove more solids. This involves passing the clear water through filters with various pore sizes and materials like sand, gravel, and charcoal. These filters take out dissolved particles and harmful microorganisms like dust, chemicals, parasites, bacteria, and viruses. Activated carbon filters are also used to eliminate unpleasant smells.

Except for filters, a microfiltration or ultrafiltration membrane can also be used to filter smaller particles in the water. This kind of filtration method contains pores that only enable small molecules like water to pass through.

2.1.4. Disinfection

During disinfection, water treatment plants might put in chemicals such as chlorine, chloramine, or chlorine dioxide to destroy any rDemaining parasites, bacteria, or viruses. It also keeps the water clean as it flows through the pipes.

2.2. Organic treatment

2.2.1. Microorganisms and bacteria

Normally, the present of microorganisms as water treatment method is for removing excessive nutrients.

Nitrogen is a significant nutrient for plants and animals, but overabundance of nutrients in water can cause severe eutrophication, resulting to harmful algae such as cyanobacteria, Diatoms and Dinoflagellates to bloom and producing toxins in the water[7]. Thus, removing nitrogen from the water is important. The nitrogen often exists in water in the form of nitrite or nitrate. In order to get rid of the excess amount of this nutrient, facilities can use microorganisms that can go through denitrification, turning nitrate or nitrite into nitrogen gas and releasing it into the atmosphere.

2.2.2. Aerobic biodegradation and Activated sludge reactor

Activated Sludge Process:

The principle of this activated sludge process is to boost biological breakdown efficiently within a limited space.

This is a relatively simple system with simple processes (see *Figure 1)*:

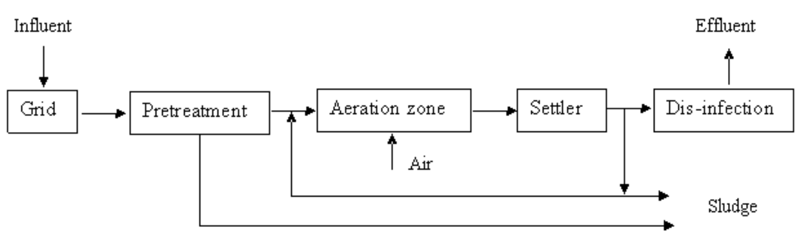

Figure 1: Schematic of activated sludge process[8][9]

ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

Wastewater goes into the aeration tank with organic materials like food waste and feces. Since these microorganisms require oxygen to live, the tank is aerated, often using diffuser systems. At the same time, the microorganisms in the incoming water settle in the tank, turning organic waste into ATP, which supports their own growth, and produce CO2 and water as byproducts.

Next, the water flows to the secondary sedimentation tank, which is also called a secondary clarifier, within which certain microorganisms are settled. This is used to maintain the right balance of microorganisms, organic waste, and oxygen. Then, when flocculants are added, these microorganisms cluster together with particles and settle as activated sludge. A portion of this activated sludge is then reintroduced into the aeration basin, allowing for a substantial increase in the microorganism population – potentially up to 30 times more than the inflow of the initial raw water[10].

On the other hand, the remainder of the activated sludge is extracted as waste sludge, thickened, and can be utilized as fertilizers, for example.

2.2.3. Membrane bioreactor

Membrane bioreactor (MBR) includes both a membrane technique such as microfiltration or ultrafiltration and a bioreactor that supports suspended growth. This process is extensively employed for treating municipal and industrial wastewater(see *Figure 2)*.

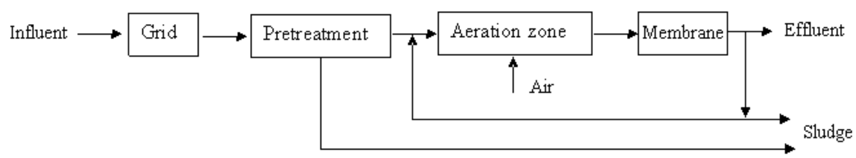

Figure 2: Schematic of the membrane bioreactor[11]

The concept is similar to the prior activated sludge process, with the key difference being that MBR replaces the traditional settlement step with a more efficient membrane-based separation, reducing reliance on water's oxygen concentration.

2.2.4. Constructed wetland

Wetland is place where water covers the soil. And a constructed wetland is a human-made wet area that functions like a natural wetland, combining water, soil, plants, tiny organisms, and animals(see *Figure 3)*.

This is also a place to remove toxic pollutants and dirt from water. There are multiple processes that the natural wetland carries out, including "sediment trapping, nutrient removal and chemical detoxification"[12]. To be specific, plant roots offer space for bacteria to live and bread, and the bacteria in wetland are ab. These plants also release oxygen, which dissolves in the water and helps bacteria remove some contaminants.

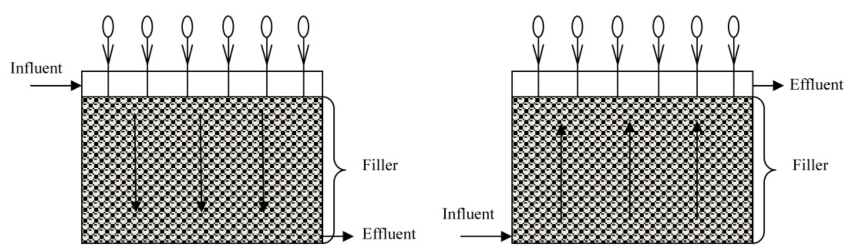

Figure 3: Schematic of constructed wetland and the floating direction of water through the wetlands. [13]

3. Case 1: McAllen Northwest conventional surface water treatment facility

The McAllen Northwest facility locates in Texas, US. It follows a traditional surface-water treatment method, turning untreated, or "raw," water into safe drinking water. This process involves removing harmful microorganisms, as well as sediment, debris, and organic matter from the raw water. Additionally, water treatment enhances the taste, appearance, and smell of the raw water (see *Figure 4 and Figure 5)*.

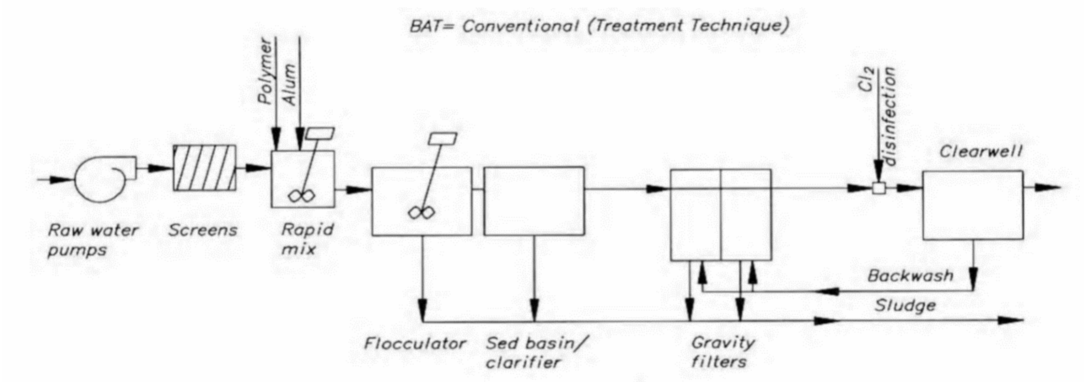

Figure 4: Processes and schematic of McAllen Northwest conventional surface water treatment facility[14]

In this water treatment system, it first goes through pre-disinfection. Several chemicals such as chlorine dioxide (ClO_2), used to eliminate germs and enhance the treatment procedure, as well as Aluminum Sulfate ($Al_2(SO_2)_3$), intended to promote the aggregation of substances in water are introduced.[15]

Then, water experiences Coagulation and Flocculation, moving into mix tanks to fully mix water with the chemical and promote the formation of flocs. There are one coagulation chambers and six flocculation chambers, each with the size of about 4 meters long*3 meters long*4.5 meters deep, which is a very large scale.

Through sedimentation, the flocs in the water accumulate at the bottom in two sedimentation basins. The flocs are filtered out in the filtration facility containing layers of filters such as sand, coal, and rock (Figrue. And the remaining sludge is pumped to concrete lined water tanks. At last, there is a secondary disinfection stage, where chloramines (NH_2Cl) are added to prevent bacterial infection and ensure water quality.

Figure 5: Filtration facility at McAllen Northwest [16]

Benefits and Costs:Efficacy: The water resulting from this McAllen Northwest facility are clean drinkable water for human consumptions.

Table 1: Quality measures of incoming raw water and outgoing treated water at McAllen Northwest.

Substance	Units[a]	Incoming Level	Outgoing Levels			Maximum Contaminant Level (MCL)[b]
			Min.	Max.	Avg.	
Regulated Contaminants						
-Arsenic	ppb		3	3	3	10
-Barium	ppm		.097	.109	.103	2
-Fluoride	ppm		.42	.43	.43	4
-Gross Beta Emitters	pCi/L		4.5	5.8	5.15	50
-Nitrate	ppm		.12	.24	.18	10
-Selenium	ppb		0	3.1	1.6	50
-Total Organic Carbon	ppm	5.49	3.18	4.37	3.71	25% Removal[c]

[17][18]The Maximum contaminant Level (MCL) is the maximum level of a contaminant permitted in potable water.

According to Table 1 above, all the measured substances, the possible contaminants present in water, are below the maximum contaminant level, which proves the quality of water supported by McAllen Northwest facility.

ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

Capacity: When designed and planned, the McAllen Northwest facility has a maximum capacity of up to 3,000,000,000 gallons annually of clean drinkable water working 100% effort for 365 days, which equates approximately 8,250,000 gallons per day.

And with limiting factors of facility operations, on average, the McAllen Northwest water treatment facility can produce 2,349 million gallons water per year, which is 78% of the maximum designed capacity.

Economic costs: Through calculations, the initial construction cost of McAllen Northwest facility was 21,300,000 dollars, which are divided into several categories such as “Overbuilds and Upgrades” and the “Raw water reservoir”, which takes up a large part of construction costs of the facilities[19].

4. Case 2: Los Filtros Water Treatment Plant[20]

The Los Filtros Guaynabo Water Treatment Plant (WTP) is situated in the northern coastal valley of Puerto Rico in Guaynabo. The Guaynabo WTP operates as a conventional filtration facility for drinking water.

The process starts with raw water entering a rapid mixing chamber where a chemical coagulant is introduced. After this pre-treatment, the water proceeds to the flocculation basin and then to one of five sedimentation tanks, where floc settles out of the water. Subsequently, the settled water goes through eighteen sand filters to further remove dissolved substances. Following filtration, the water is treated with chlorine for disinfection before being transferred to the distribution tank. The facility is mandated to adhere to regulations established under the Safe Drinking Water Act, including compliance with the Environmental Protection Agency's (EPA) Stage 2 Disinfectant/Disinfection By-Product (D/DBP) Rule (EPA 2009).

Regional balance: UV254 monitoring

This Los Filtros water Treatment plant was built near a river, and the source of water was the Bayamón river basin, originating in the mountains and flowing into the that river along with its primary tributary. Over time, human and natural impacts increased the organic matter, making the rivers murky and containing a high concentration of natural organic matter such as human-made substances and pollutants from human activities in the surrounding areas[21]. When heavy rainfall occurs on the island, it leads to soil erosion, causing the rivers in the basin to become quite turbid and appear reddish in color. These conditions, characterized by high organic content, color, and turbidity, have consistently presented operational difficulties for the treatment plant.

Different from regular conventional water treatments, this Los Filtros Water Treatment Plant has a UV254, which is the ultraviolet absorbance at 254 nanometers, to monitor and measure the number of organic matters in water. This can give a very good overview of the right amount of chemicals that should be used.

Benefit: This system has certain tolerance of various weather, climate, and accidental conditions, with small influences when facing small weather changes such as seasonal variations, and with moderate effects when facing substantial rainfalls or unexpected contamination incidents.

Capacity: This facility has the ability to provide around 25,000,000 to 30,000,000 gallons per day (MGD) of fresh water, which caters to roughly 256,000 residents in the vicinity. [22]

Costs: Environmental costs: The average chemical coagulant usage per month was about 100,000 pounds. After Coagulation process, a significant sludge (things left behind of water) quantity can form. It's estimated that this sludge may reach up to 0.5 percent of the treated water's volume. This may be a problem because they cannot be reused for lands: his sludge often contains metal hydroxides and is typically highly alkaline, with a pH level of 10 or above because of the chemicals during reactions.

Economic costs: Due to the hazardous nature of this sludge, companies are forced to allocate substantial financial resources to either treat it or to transport and dispose of it. In certain instances, the cost of managing and disposing of the resulting sludge surpasses the expenses associated with treating the wastewater itself.

5. Case 3: The WaterHub at Emory University

The WaterHub at Emory University contains a pioneering water recycling system utilizing ecoengineering techniques to purify wastewater, preparing it for subsequent non-drinking purposes such as toilet flushing(see Figure 6). With solar panels to power the facility, the WaterHub at Emory University also consists of several inventive and validated procedures that collect, treat, and distribute water to designated reuse areas throughout the campus. To analyze, it is very important to understand these processes used in the WaterHub(see Figure 7):

Figure 6: WaterHub greenhouse at Emory University.

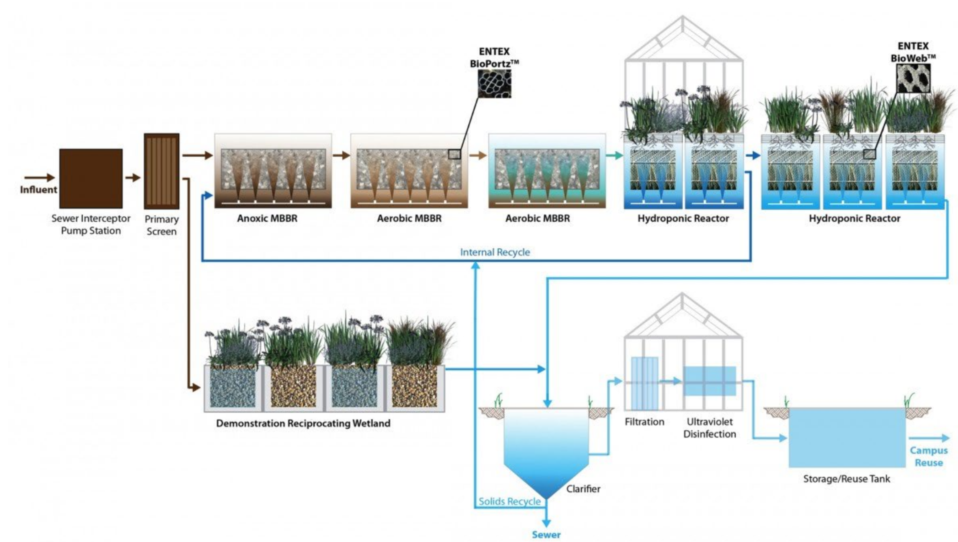

Figure 7: Schematic of the WaterHub water treatment process

After collecting wastewater on the Emory campus, it first simply goes through a screen to remove wastes and debris from that wastewater.

5.1. Regional pattern: a combination of aerobic and anaerobic bioreactors

The water first flows into an anoxic setting, an oxygen-deprived place with <0.5mg/L of dissolved oxygen, where microorganisms are arranged in a honeycomb structure that is a suitable habitat for these microbes to initiate the process of breaking down nutrients such as nitrogen through metabolism.

Then the wastewater goes through the aerobic moving bed bioreactors, which means abundant oxygen in them. With microbes continuously treating the wastewater, the oxygen in that place starts to react with a large fraction of harmful carbonaceous materials. At the same time, these bioreactors also contain charcoal filters to remove odorous gasses from the wastewater.

And then through the hydroponic bio-habitats consisting of green plants, beneficial insects, organisms, and roots of vegetables, the water undergoes process that further reduces excessive nitrogen, carbon, and other poisonous chemicals.

Instead of individual anaerobic or aerobic reactors, the pairing of anaerobic and aerobic reactors proves more effective in breaking down organic pollutants. The anaerobic step can change the nature, or the biochemical property of the wastewater, improving the performance of the subsequent aerobic phase. This combination of reactors also enhances the stability of the entire system.

Also, adding a series of system, including anaerobic bioreactors, aerobic bioreactors, the wetland and the UV light, enables a strong water treatment system

5.2. Into the wetland

A portion of this water is then transferred to a nearby reciprocating wetland. This constructed wetland in Emory University is designed to replicate the natural ebb and flow of tidal marshes, with a great number of microorganisms that help break down waste can be found.

5.3. Regional pattern: The UV light

Through ultraviolet light, the reclaimed water undergoes a process which means the microorganisms are subjected to UV light, and UV light targets the genetic code and causes alterations in the DNA/RNA of these organisms, thereby incapacitating the microorganism's capability to function and reproduce[23]. Subsequently, the clean water is conveyed via pipelines to the campus facilities and buildings, specifically for the purpose of toilet flushing.

This addition of UV light corresponds to the climate and weather of the site of Emory. In Los Angeles, California, the city where Emory sits, contains mostly good weathers with sunny conditions. According to the approximate records, the annual days with sun near the Los Angeles Airport is 263 days, and the annual sunny days near the Los Angeles Downtown is 292 days. Both numbers are much higher than the US average sunny days of 205 days per year[24].

And in California, the annual average UV index is about 5.2, while the US annual average UV index is only 4.3, showing that the weather conditions in CA really supports the use of ultraviolet light to kill harmful bacteria and other microorganisms[25].[26]

5.4. Benefits

This water filtration and recycling process mainly uses green plants and microorganisms, which are very sustainable and environmentally friendly. As stated by Gina McCarthy, who is the former administrator for the United States Environmental Protection Agency, “The WaterHub isn’t a typical treatment facility. It filters wastewater through plant roots and microbes clean out organic material. A model for us all”[27]!

Capacity:After this groundbreaking system was installed in 2015, it has the impressive capacity to recycle up to 400,000 gallons of water on a daily basis, covering almost 40 percent of the entire water demand for Emory's campus[28]. The bulk of this water is allocated for consumption by both the steam plant and five chiller plants on the campus. These utility facilities presented a valuable chance to replace a substantial segment of the campus's reliance on potable water with a dependable and environmentally friendly water source.

Costs:However, the potential problem of filtrating water with microorganisms and plants is that it cannot be as thorough as industrial filtration, meaning that the reclaimed water can only be used for non-drinking purposes such as flushing the toilets instead of drinking and consuming. This issue can be solved by adding other water filtration systems to remove things like residual chlorine, heavy metals, bacteria, silt, and rust from water.

6. Case 4: Extended Aeration Activated Sludge Treatment Plant in Residential College

This water treatment plant is located in the residential college in UiTM Sarawak Branch, Samarahan Campus[29]. It mainly employs the activate sludge process for its water recycle, which is as shown in Figure 8.

ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

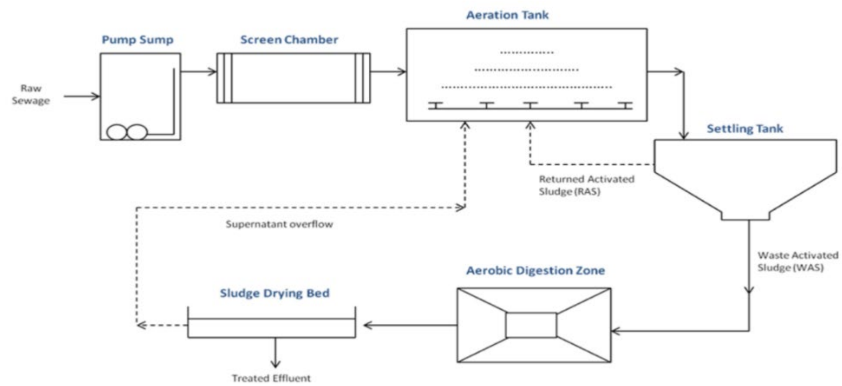

Figure 8: Schematic of the WaterHub water treatment process

The principle of this activated sludge process is to boost biological breakdown efficiently within a limited space.

This is a relatively simple system with simple processes:

Wastewater goes into the aeration tank with organic materials like food waste and feces. Since these microorganisms require oxygen to live, the tank is aerated, often using diffuser systems. At the same time, the microorganisms in the incoming water settle in the tank, turning organic waste into ATP, which supports their own growth, and produce CO2 and water as byproducts.

Next, the water flows to the secondary sedimentation tank, which is also called a secondary clarifier, within which certain microorganisms are settled. This is used to maintain the right balance of microorganisms, organic waste, and oxygen. Then, when flocculants are added, these microorganisms cluster together with particles and settle as activated sludge. A portion of this activated sludge is then reintroduced into the aeration basin, allowing for a substantial increase in the microorganism population – potentially up to 30 times more than the inflow of the initial raw water[30].

On the other hand, the remainder of the activated sludge is extracted as waste sludge, thickened, and can be utilized as fertilizers, for example.

The MBR is better at removing organic pollutants and ammonia than the activated sludge method. Additionally, the MBR can handle wastewater with more suspended solids, which means it needs less space to handle the same amount of pollutants compared to the activated sludge process.

Benefits and Costs:

Environmental benefits:By using microorganisms and this biological water treatment, it is very sustainable and friendly to the environment. By using plants instead of energy driven machines, they cost less energy to operate and filter.

In addition, the remainder of the activated sludge is extracted as waste sludge and thickened. These sludge does not contain additional harmful chemicals. As a result, this waste sludge can be safely recycled, using for further fertilizations and lands.

Costs: Biological water treatment can be limited by the geographical and climatic conditions. It was hugely affected by the climate, meaning that it does not have good stability when weather and climate are constantly changing. This biological way is suitable for Malaysia owing to its temperate climate. Furthermore, the pH and temperature within the treatment facility consistently remained within the optimal range for effective process performance. Thus, the extended aeration activated sludge method proves to be an appropriate treatment system.

7. Conclusion

According to all the analyses and data provided (see *Table 2)*, we can draw conclusions regarding conventional and biological water recycling processes.

ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

Table 2 The comparison of four cases in different categories of water treatment

	Case1: McAllen Northwest conventional surface water treatment facility	Case2: The WaterHub at Emory University	Case3: Extended Aeration Activated Sludge Treatment Plant in Residential College.	Case4: Los Filtros Water Treatment Plant
Conventional/Biological	Conventional	Conventional	Biological	Biological
Treatments used	pre-disinfection, coagulation and flocculation, sedimentation, filtration, disinfection	coagulation and flocculation, sedimentation, filtration, disinfection, UV254 monitoring	aerobic and anaerobic bioreactors, constructed wetland, UV disinfection	Activated sludge
Regional pattern		UV254 monitoring	UV disinfection	Activated sludge
Capacity	3,000,000,000 gallons/year 8,250,000 gallons/day	20,000,000 to 30,000,000 gallons per day	400,000 gallons/day	
Efficacy	Black/gray water to drinkable freshwater	Black/gray water to drinkable freshwater	Black water to non-drinkable water(gray water). Water used for flushing toilets	Gray water
Economic costs	21,300,000 dollars			
Environmental costs	Chemicals used in coagulation and disinfection process	Chemicals used in coagulation and disinfection process		
Local Adaptability	Widely used	Widely used	Climate and weather dependent, moderate and mild weathers	Climate dependent

Conventional water treatment processes generally boast a much larger capacity, ranging from millions to tens of millions of gallons of water produced every day. These processes can effectively produce high-quality drinking water. The high adaptability of conventional water treatment allows for its widespread use globally. However, the chemicals used in processes such as coagulation and disinfection result in toxic sludges or sediments, requiring significant effort for disposal. Improper management of these residues by companies or government entities could harm the environment.

On the other hand, biological water treatment, which involves using organisms and plants to filter water, has a lower capacity, typically producing thousands of gallons of water daily. The efficacy of this type of treatment is relatively low, with the maximum output being gray water and non-drinkable water suitable for flushing toilets. It is also highly dependent on environmental factors such as climate and weather, performing best in moderate and mild conditions with sufficient sunlight. However, these processes do not produce toxins, aligning with our sustainability goals.

In the end, if the demand of clean water is not urgent, and if people are able to reduce the amount of water consumed to some extend, the biological methods of water treatment are more sustainable and offer greater benefits to our surrounding environment. People should pay much attention to these treatment methods because of their economic and ecologic superiority.

References

[1] Posner, A., & Covitt, B. (2023, August 2). Earth's Fresh Water. National Geographic . https://education.nationalgeographic.org/resource/earths-fresh-water/
[2] United Nations, & Division. (n.d.). — SDG Indicators. United Nations-Department of Economic and Social Affairs . Retrieved September 13, 2023, from https://unstats.un.org/sdgs/report/2022/Goal-06/
[3]intergovernmental panel on climate change. (2022). Fact sheet - Food and Water. Sixth IPCC Assessment Report. https://www.ipcc.ch/report/ar6/wg2/downloads/outreach/IPCC_AR6_WGII_FactSheet_FoodAndWater.pdf
[4] Kosuth, M., V. Wattenberg, E., & Orb Invisibles Final. (2017, May 16). Invisibles Final Report — Orb Media. Orb Media. https://orbmedia.org/invisibles-final-report
[5] Parker, L., & National Geographic. (2015, September 2). Nearly Every Seabird On Earth Is Eating Plastic. National Geographic. https://www.nationalgeographic.com/science/article/15092-plastic-seabirds-albatross-australia
[6] Centers for Disease Control and Prevention. (2022, May 16). Water Treatment | Public Water Systems | Drinking Water | Healthy Water | CDC. CDC. https://www.cdc.gov/healthywater/drinking/public/water_treatment.html
[7] Water Resources Mission Area. (2019, January 3). Nutrients And Eutrophication | U.S. Geological Survey. USGS. https://www.usgs.gov/mission-areas/water-resources/science/nutrients-and-eutrophication

ISSN 2616-5872 Vol.5, Issue 9: 77-86, DOI: 10.25236/AJEE.2023.050910

[8] Zheng, C., Zhao, L., Zhou, X., Fu, Z., & Li, A. (2013). Treatment Technologies for Organic Wastewater. In W. Elshorbagy & R. K. Chowdhury (Eds.), Water Treatment . IntechOpen. https://doi.org/10.5772/52665
[9] Activated Sludge Process, Design Criteria - Engineering Articles. (n.d.). Engineering Articles. Retrieved September 13, 2023, from https://www.engineeringarticles.org/activated-sludge-process-design-criteria-advantages-disadvantages/
[10] Karl-Uwe Schmitz. (2019, August 6). Activated Sludge Process And IFAS - Design Rules + Guideline. YouTube. https://www.youtube.com/watch?v=ciPFC3Y2rkg
[11] Zheng, C., Zhao, L., Zhou, X., Fu, Z., & Li, A. (2013). Treatment Technologies for Organic Wastewater. In W. Elshorbagy & R. K. Chowdhury (Eds.), Water Treatment . IntechOpen. https://doi.org/10.5772/52665
[12] Wetland Functions And Values: Surface And Ground Water Protection | Department Of Environmental Conservation. (n.d.). Agency of Natural Resources-Department of Environmental Conservation. Retrieved September 13, 2023, from https://dec.vermont.gov/watershed/wetlands/functions/water-quality
[13] Zheng, C., Zhao, L., Zhou, X., Fu, Z., & Li, A. (2013). Treatment Technologies for Organic Wastewater. In W. Elshorbagy & R. K. Chowdhury (Eds.), Water Treatment . IntechOpen. https://doi.org/10.5772/52665
[14] Jurenka, R., S. Martella, and R. Rodriguez. 2001. "Water Treatment Primer for Communities in Need." Available at: http://www.usbr.gov/pmts/water/media/pdfs/ report068.pdf. Accessed on 1 September 2023.
[15] Buffalo Water Authority. 2005. "2004-2005 Annual Water Quality Report." Available at: http://www.buffalowaterauthority.com/water_quality_report.htm. Accessed on 1 September 2023.
[16] Sturdivant, A.W. (2006.) Extension Associate Economist. Texas AgriLife Extension Service. Weslaco, TX. Provided photographs of McAllen Northwest facility.
[17] Rogers, C. (2008). Economic Costs Of Conventional Surface-Water Treatment: A Case Study Of The Mcallen Northwest Facility.
[18] Environmental Protection Agency. (2008.) "Drinking Water Contaminants." http://www.epa.gov/safewater/contaminants/index.html.
[19] McAllen Public Utilities Water Systems. (2002.) "Initial Construction Budget-Pay Estimate for McAllen Northwest Water Treatment Plant." Copy provided by Javier Santiago, McAllen, TX.
[20] CASE STUDY: PUERTO RICO WTP SAVES THOUSANDS WITH UV254. (2018, January 5). Real Tech Water. https://realtechwater.com/blog-post/case-study-puerto-rico-wtp-saves-thousands-with-uv254/
[21] Cáceres Acosta, N M. (2013). "Monitor Source Water UV254 to Enhance Operations in WT Plant [22] Los Filtros Guaynabo". 19th Drinking Water Seminar Puerto Rico. May 23, 2013.
Encarnación Martínez, T. Y., & Rosa Rosado, L. (2022). Analysis of Rehabilitation of the Sludge Treatment System at Guaynabo Water Treatment Plant, "Los Filtros." http://hdl.handle.net/20.500.12475/1615
[23] Learn About UV Water Purification | ESP Water Products. (n.d.). ESP Water Products. Retrieved September 14, 2023, from https://www.espwaterproducts.com/understanding-uv-water-filtration-sterilization/
[24] California Climate: Average Temperature, Weather By Month, California Water Temperature. (n.d.). Climate Data. Retrieved September 14, 2023, from https://en.climate-data.org/europe/united-kingdom/england/california-657474/
[25] Climate In California. (n.d.). Best Places. Retrieved September 14, 2023, from https://www.bestplaces.net/climate/state/california
[26] Reusing On-Site Water At Emory University | Better Buildings Initiative. (n.d.). Better Buildings-U.S. Department of Energy. Retrieved September 14, 2023, from https://betterbuildingssolutioncenter.energy.gov/implementation-models/reusing-site-water-at-emory-university
[27] The WaterHub at Emory University. (n.d.). Sustainable Water. Retrieved September 14, 2023, from https://cliftoncommunitypartnership.org/documents/emory-waterhub-case-study-1.pdf
[28] Emory Magazine. (2020). Smarter Water: Emory's WaterHub. Emory University-Water. https://news.emory.edu/features/2020/04/waterhub/#group-Study-and-Research-0mBShHER1V
[29] Sofwan, N. M., Idris, J., Azir, K. M. A. K., Hadi, N. A., Ali, S. N. A. M., Hassan, N. A., Wakimin, N. D., Francis, L. D., & Abdullah, M. F. (2020). Process Design and Physicochemical Characterization of Extended Aeration Activated Sludge Treatment Plant: A Case Study. Journal of Asian Scientific Research, 10(3), 121–130. https://doi.org/10.18488/journal.2.2020.103.121.130
[30] Karl-Uwe Schmitz. (2019, August 6). Activated Sludge Process And IFAS - Design Rules + Guideline. YouTube. https://www.youtube.com/watch?v=ciPFC3Y2rkg