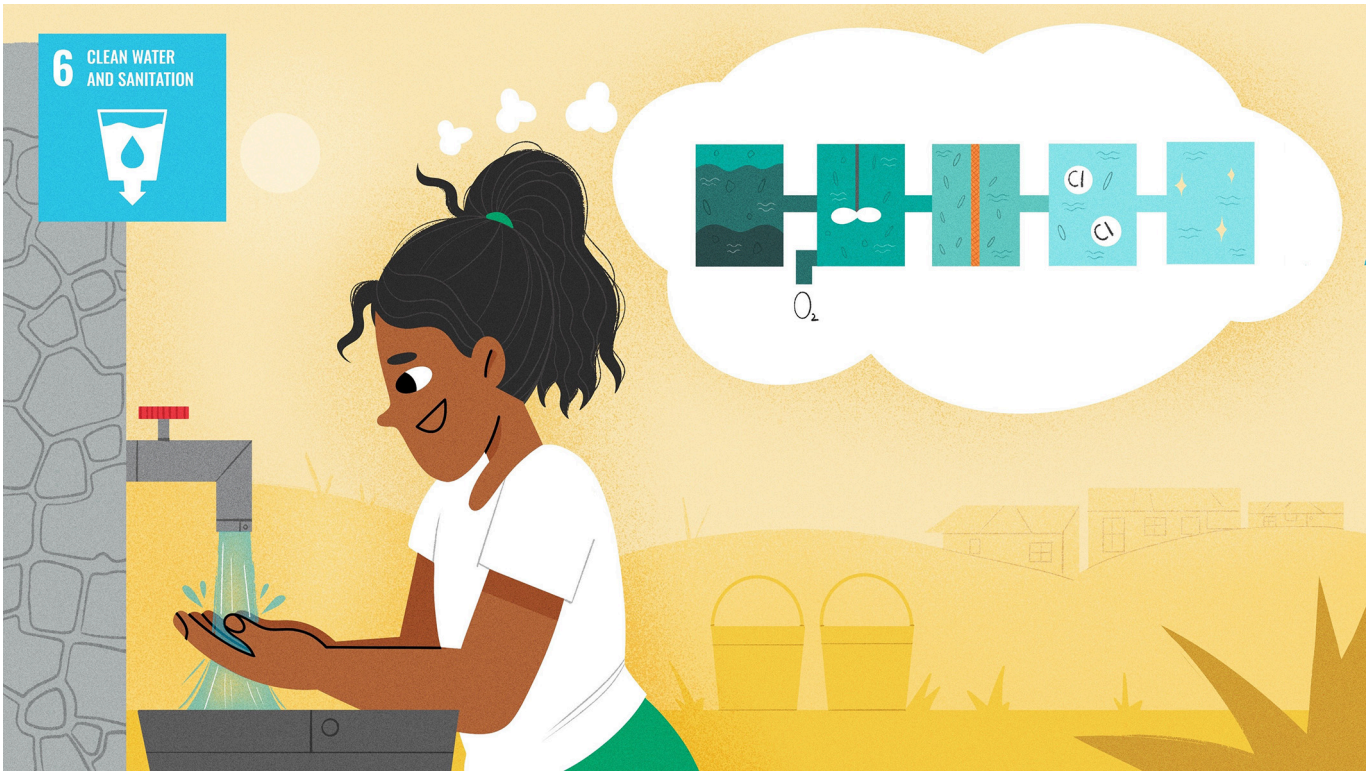
frontiers | Frontiers for Young Minds

ENGINEERING AND TECHNOLOGY
Published: 28 November 2024
doi: 10.3389/frym.2024.1418929



TOWARDS SDG 6: WASTEWATER TREATMENT GENERATES A PRECIOUS WATER RESOURCE

Bothayna Al-Gashgari [1,2]***, Fatimah Almulhim*** [1,2]***, Claudia Sanchez-Huerta*** [2] ***and Pei-Ying Hong*** [1,2*]

[1] *Bioscience Program, Biological and Environmental Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia*

[2] *Center of Excellence on Sustainable Food Security, Division of Biological and Environmental Science and Engineering, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia*

YOUNG REVIEWERS:


ARNAU
AGE: 12


CARTER
AGE: 12


IMRAN
AGE: 11


ISLA
AGE: 12

Clean drinking water and good toilet facilities are important for our health and wellbeing. Sadly, around 2.2 billion people worldwide do not have clean drinking water or good toilet facilities. We need to work together to fix this problem. Because of this, the United Nations created a big goal called Sustainable Development Goal (SDG) 6. This goal involves understanding all the water sources on Earth and using them smartly. It also highlights the importance of being aware of water wasted, especially in areas with little water available, and finding solutions for water shortages. In this article, you will learn about wastewater treatment technology, in which dirty water is cleaned so we can reuse it. The goal is to create a nonstop cycle, reusing water repeatedly, similar to how nature works. We can care for people *and* the planet by being smart about water use.

LINAR

AGE: 11

RAPHAEL

AGE: 12

Watch an interview with the authors of this article to learn even more! (Video 1).

SDG 6—CLEAN WATER AND SANITATION

Have you ever asked yourself where water comes from? If your answer is from the tap, you are in the 74% of the luckiest people in the world's population because you have immediate access to water [1]. Water is vital for all life on Earth and it is necessary for our daily routines. Sadly, more than two billion people do not have access to clean water due to poor hygiene systems. Not all water is safe to use directly. Before we can use water from under the ground, we must pump it up to the surface. Surface water must be treated first to remove chemicals and microorganisms, such as bacteria and viruses. Finally, seawater is too salty to drink, so we must remove the salt to use it. Many countries have dangerously low water supplies because they are located in dry regions with low rainfall, such as Saudi Arabia. This natural risk can get worse when countries' groundwater levels drop. Sadly, ~22 nations are at serious risk of experiencing water shortages [1].

We must take care of our water resources and think about how we can use them wisely. That is why the United Nations created Sustainable Development Goal (SDG) 6: Clean Water and Sanitation. As part of the 17 Goals created to make our planet healthier, SDG 6 is about finding solutions to the world's water crisis and ensuring everyone can afford to drink clean water and use clean facilities. This goal also aims to reduce pollution and the release of dangerous chemicals and materials into the environment, to avoid contaminating our precious water sources [2].

SDG 6 also highlights one hidden water source that is often forgotten: **wastewater**, the water that is discarded after use. Treating wastewater can be more difficult than treating other water sources mentioned above, but it is the only water source available in all countries. Using treated wastewater as a primary water source can be a great way to save water so we can keep our water supply steady and take some of the pressure off freshwater resources. It is a big challenge, but together we can achieve it! Singapore is an excellent example of making the SDG 6 goal come true. Did you know Singapore, a small island country with a 5–7 million people, has no groundwater? The country also cannot fully capture and store all the abundant rainfall it receives [3]. But Singapore has come up with a great solution by focusing on reusing treated wastewater. This has allowed them to achieve a continuous water loop, making sure that no water goes to waste [3]. It is incredible how technology can help us solve some of our biggest challenges!

WASTEWATER

Water that contains pollutants and would require purification.

WHO GENERATES WASTEWATER?

Did you know that everyday activities like using the toilet, taking a shower, and doing laundry produce a lot of wastewater? For example, a single flush of the toilet creates about 6 L of wastewater, a 10-min shower generates 65 L, and one load of laundry can produce up to 95 L. Even making everyday products requires a lot of water. For instance, it takes 822 L of water to produce just 1 kg of apples and a staggering 15,000 L of water for 1 kg of meat. Making a shirt requires 2,700 L of water, and even producing an iPhone needs 12,000 L of water. We generate a lot of wastewater daily, so it is important to clean and reuse this water to protect the environment and conserve resources [4].

TYPES OF WASTEWATER TREATMENTS

Do you want to learn about the history of wastewater treatment? Let us start from the 18th century, when people discovered that dumping wastewater into rivers made the water dirty. Sadly, the dirty water caused illnesses in people who drank from those rivers. To solve this problem, the first wastewater treatment plant (WWTP) was built to lower the pollution present in wastewater (Figure 1A). How did it work? First, the dirty water went through a long horizontal basin, called a **sedimentation** basin, where dirt would settle out at the bottom. Then, the water ran through a vertical tank containing sand and gravel of various sizes, acting as a filter to trap smaller dirt—a process called **filtration** [4]. In 1854, WWTPs started adding chlorine at the end of the treatment to kill bacteria and other pathogens—this process is called **disinfection** (Figure 1B) [4]. Then, in 1913, two scientists found specific microorganisms (good bacteria) that breathe oxygen, eat pollutants in wastewater, and clean it. Using these bacteria to clean wastewater is called an **activated sludge** method. The good bacteria can then be removed, and water is disinfected and released into the environment as clean water (Figure 2A). The activated sludge method is more efficient and faster than normal filtration. This method is still being used for wastewater treatment; however, scientists are discovering even better ways to clean wastewater to satisfy the needs of growing populations in big cities [4].

A NEW, EFFICIENT WAY TO CLEAN WATER

Wastewater treatment requires a lot of energy. Since most of the world's energy still comes from fossil fuels, we need to find ways to use as little energy as possible for everything we do, while transitioning to renewable energy like solar or wind. So, our team of scientists started working on new technology to clean wastewater easily using less energy. We developed a new method using tiny **anaerobic** microorganisms. These microorganisms work in the absence of

SEDIMENTATION

The process whereby big particles settle to the bottom of a solution over time.

FILTRATION

The process during which particles are removed from water by means of size separation.

DISINFECTION

The process by which chemicals or ultraviolet (UV) light are applied to treated water to ensure that bacteria and other dangerous organisms are killed.

ACTIVATED SLUDGE

A process in which helpful bacteria clean wastewater by eating pollutants and forming clumps that are removed, making the water safe to release back into nature.

ANAEROBIC

A condition in which no oxygen is present.

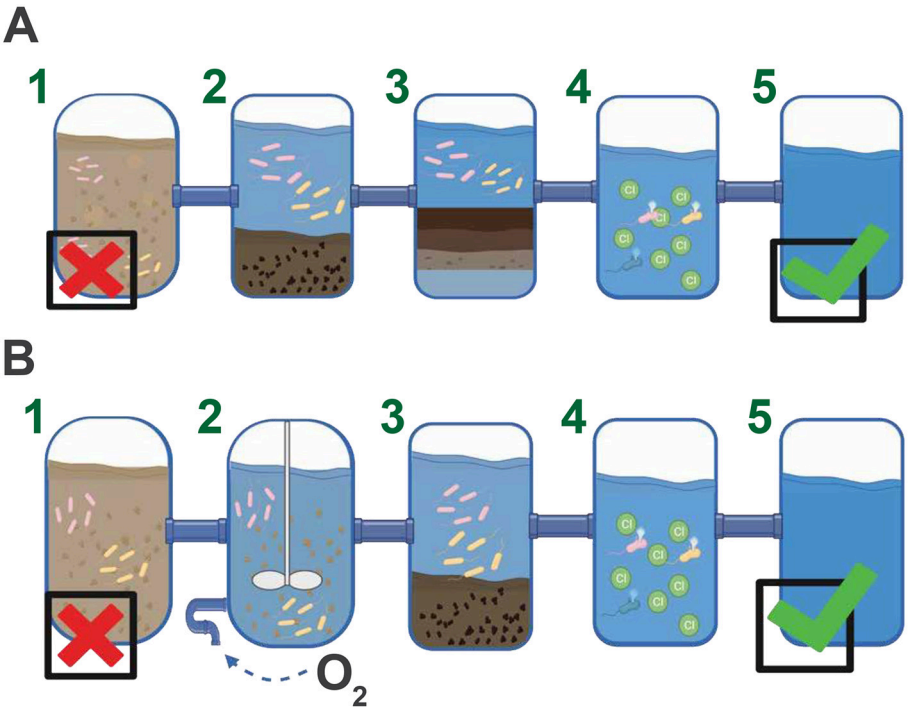


Figure 1

Figure 1

(A) The first WWTP worked by (1) collecting wastewater and (2) sending it to large sedimentation basins to allow big particles to sink to the bottom. (3) A layer of sand and gravel acted as a filter for smaller particles. (4) Chlorine disinfection was used to kill remaining microorganisms, producing (5) clean, treated water. **(B)** In a later method, called the activated sludge method, (1) wastewater goes to a basin and (2) good microorganisms are added. The microorganisms eat organic waste in the wastewater. This is followed by (3) sedimentation and (4) disinfection, also resulting in (5) clean, treated water.

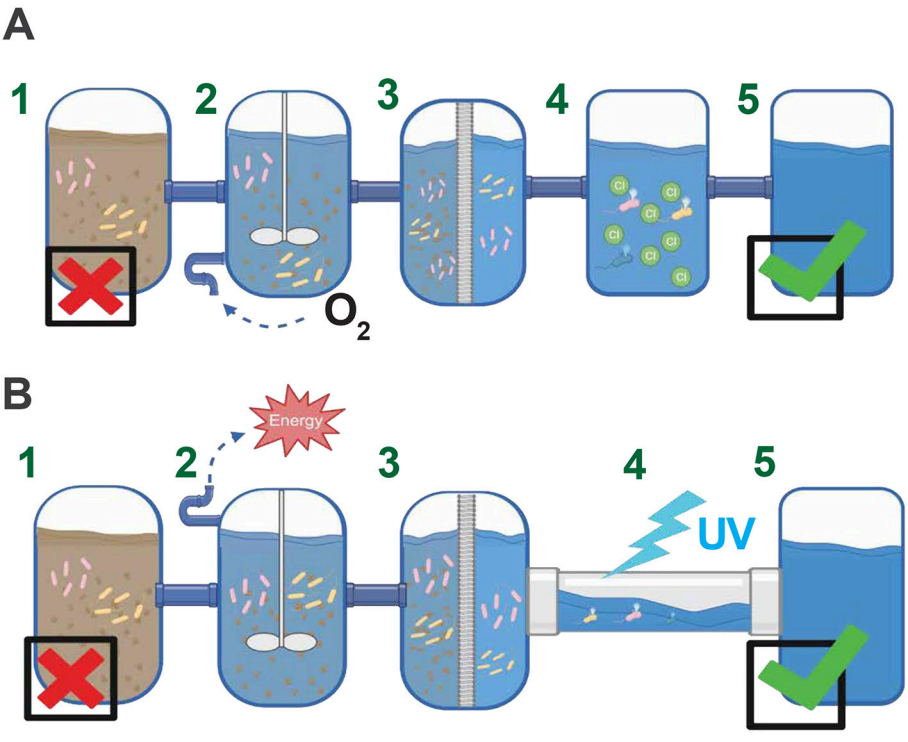


Figure 2

Figure 2

(A) Nowadays, (1) wastewater goes through (2) activated sludge treatment followed by (3) membrane filtration to remove fine particles, and (4) chlorine disinfection is used to enhance the water quality. **(B)** An alternative form of (1) wastewater treatment technology is done in (2) anaerobic conditions, where microorganisms consume organic matter in the absence of oxygen to produce methane. This is followed by (3) membrane filtration and (4) disinfection using UV exposure, and finally resulting in (5) clean, treated water.

oxygen and break down the dirt in the wastewater, turning it into methane gas. Methane can be collected and used as an energy source for the WWTP or even for other processes.

ANAEROBIC MEMBRANE BIOREACTOR

An engineered system that is operated in the absence of oxygen and is equipped with membrane filtration.

We then combined the use of anaerobic microorganisms with membranes in a system called an **anaerobic membrane bioreactor**. "Bioreactor" refers to the biological reaction that occurs when the good bacteria are treating the wastewater. We also added a final disinfection step using UV light, which can kill microorganisms by damaging their DNA (Figure 2B). What did we get? Clean water that has extra nutrients that are excellent for plants and for growing food! To test this new process in the real world, we built a small-scale demonstration WWTP in Saudi Arabia. This plant is larger than a lab-scale demonstration but smaller than a full-size WWTP. The plant is currently in operation and, so far, it has demonstrated that we can get clean water that is perfect for plant growth without using any energy sources other than the energy generated by the process itself [5]!

WHAT HAVE WE DISCOVERED?

In this article, we discussed a very important problem—water shortage. The United Nations has called for help from scientists and citizens, so that everyone comes together to find solutions to fix this problem. Everyone can help by being smart when using the water that they have available. Remember that everyone uses water, and everyone produces wastewater. So, it is everyone's responsibility to act and support the achievement of SDG 6.

How can you contribute to better water use and wastewater management? You can reduce the amount of water you use, and you can raise awareness with your family and friends about the need to avoid wasting or polluting water. For example, you can shorten the length of your showers, turn off the tap water while brushing your teeth, avoid flushing medicines down the toilet, and use a bucket to collect rainwater that can then be used to water plants.

It is also important for people to trust that treated wastewater is a precious resource that can provide a steady supply of fresh water and a clean environment. It is inspiring to see that other countries are following in the footsteps of Singapore's remarkable achievement in wastewater treatment and reuse (Figure 3). These countries have successfully treated 100% of their wastewater, ensuring that the wastewater does not negatively impact the environment. These countries include Kuwait and Qatar, proving that even the most water-scarce region in the world (i.e., the Middle East) can reuse treated wastewater safely [6]. It is great to know that 58% of wastewater is already being treated worldwide [1], but we need to continue putting in our best efforts to reach the goal of treating and reusing 100% of wastewater globally.

Figure 3

The vision for future water sources. The diagram shows our final future goal: wastewater becoming 100% treated and reused. A future where (1) natural water resources can be collected and (2) treated for (3) human use, and where (4) wastewater is recollected, (5) treated, (6) reused for agriculture or industrial use, or (7) returned safely to the environment to replenish natural sources.

Figure 3

ACKNOWLEDGMENTS

We would like to thank Ruben Costa and Nicki Talbot at KAUST for their invaluable support during the initial writing stage and review process, without which this collection would not have been possible. We also extend our gratitude to the KAUST Office of Sustainability and the UNDP Saudi Arabia Country Office for their dedication to raising awareness of the UN SDGs in our journey toward a more sustainable world.

REFERENCES

1. FAO UW. 2021. *Progress on Level of Water Stress Global Status and Acceleration Needs for SDG Indicator 6.4.2*. Rome: FAO; United Nations Water (UN Water), 95. doi: 10.4060/cb6241en
2. United Nations 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. Available at: https://www.un.org/sustainabledevelopment/development-agenda/
3. Lee, H., and Tan, T. P. 2016. Singapore's experience with reclaimed water: NEWater. *Int. J. Water Resour. Dev.* 32:611–21. doi: 10.1080/07900627.2015.1120188
4. Lofrano, G., and Brown, J. 2010. Wastewater management through the ages: a history of mankind. *Sci. Total Environ.* 408:5254–64. doi: 10.1016/j.scitotenv.2010.07.062

5. Zhang, S., Tchalala, M. R., Cheng, H., Medina, J. S., Xiong, Y., and Hong, P.-Y. 2023. Anaerobic membrane bioreactor as the core technology for future decentralized wastewater treatment plants. *Curr. Opin. Chem. Eng*. 42:100975. doi: 10.1016/j.coche.2023.100975
6. WHO UN-Habitat. 2021. *Progress on Wastewater Treatment Global status and acceleration needs for SDG indicator 6.3.1*. Geneva: United Nations Human Settlements Programme (UN-Habitat) and World Health Organization (WHO).

SUBMITTED: 17 April 2024; **ACCEPTED:** 11 November 2024;
PUBLISHED ONLINE: 28 November 2024.

EDITOR: Susana Carvalho, King Abdullah University of Science and Technology, Saudi Arabia

SCIENCE MENTORS: Nicki Talbot

CITATION: Al-Gashgari B, Almulhim F, Sanchez-Huerta C and Hong P-Y (2024) Towards SDG 6: Wastewater Treatment Generates a Precious Water Resource. Front. Young Minds 12:1418929. doi: 10.3389/frym.2024.1418929

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ARNAU, AGE: 12
Hello my name is Arnau and I am 12 years old. I like science, reading, cooking and traveling the world.

CARTER, AGE: 12
I like to play sports and play piano. I am very energetic and I am good at math and science. I like snakes and had a birthday party with lots of snakes and reptiles.

IMRAN, AGE: 11
I like reading science fiction books and writing about science topics. I am a keen basketball player and enjoy being outside when the weather is not too hot.

ISLA, AGE: 12
I have a younger sister and I love cats. I love the water and marine animals... cute. I play basketball and American Football and Badminton. I went to the Maldives this year for a school trip.

LINAR, AGE: 11
I like the ocean and marine animals... and cats. I like to read comics and I am very creative with music—I like making beats. I enjoy playing badminton and silentball.

RAPHAEL, AGE: 12
I like playing football and I like watching BetaSquad on YouTube. I have watched all of the Lord of the Rings movies. I like elephants. I support Bayern Munich.

AUTHORS

BOTHAYNA AL-GASHGARI
Bothayna is a Ph.D. graduate under the supervision of Prof. Peiying Hong. Bothayna's research focuses on applied environmental microbiology, where she is currently analyzing the relevance of horizontal gene transfer within wastewater treatment plants and reuse environments in the generation of multi-drug-resistant bacteria.

FATIMAH ALMULHIM
Fatimah is a Ph.D. student under the supervision of Prof. Peiying Hong. She earned her bachelor's degree in biological sciences from California State University, East Bay, and has been working on understanding the secreted products of bacteria during her master's studies. Her main focus during her Ph.D. research is to study how bacteria form microbial mats that can impact the water quality in treated wastewater distribution systems.

CLAUDIA SANCHEZ-HUERTA
Claudia is a Ph.D. graduate from the Environmental Science and Engineering program at KAUST. She is interested in studying and improving the efficiency of biological aerobic/anaerobic processes, membrane separation processes, and using disinfection processes for the treatment of municipal wastewater and now industrial wastewater.

PEI-YING HONG

Peiying is a professor in the Division of Biological and Environmental Science and Engineering, KAUST. She obtained her Ph.D. in environmental science and engineering from the National University of Singapore, and her postdoctoral training at the University of Illinois at Urbana-Champaign. At KAUST, her Environmental Microbial Safety and Biotechnology Lab research group seeks to provide the fundamental science and goal-oriented research underpinning improvements in water health and water management globally. *peiying.hong@kaust.edu.sa