frontiers | Frontiers for Young Minds

EARTH SCIENCES
Published: 29 August 2023
doi: 10.3389/frym.2023.996462

POO IS PRECIOUS

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YOUNG REVIEWERS:


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AGE: 12


TANISHKA
AGE: 14

Human poo contains precious nutrients, but we flush it down the drain to become wastewater. Wastewater often pollutes rivers, lakes, or the ocean. The high levels of nutrients in wastewater, primarily from human poo and pee, can decrease the amount of oxygen in the ocean, killing the fish that we eat along with other organisms. In the old days, poo from humans and animals was used on farms, as fertilizer. But this is not a practical option for the large volumes of wastewater produced in cities. What if the nutrients from wastewater could be used to solve rather than to create environmental problems? Using single-celled, water-dwelling plants called microalgae to treat wastewater has many benefits. Clean water helps everyone. Recycling nutrients from wastewater and using them as fertilizers will help farmers. Also, useful products like fuels and plastics can

be made from these algae. New and cheaper wastewater treatment technologies are needed to create a better future. You could be part of the solution!

WASTEWATER TREATMENT CHALLENGES

In developed areas of the world, each person produces about 150 l of **wastewater** per day. That is about 50,000 l (12,500 gallons) per person per year, or about 10 million cubic meters for a city of 100,000 people. We use water to flush the toilet, wash our dishes, or have a shower. Normally we do not think about what happens to the water when it goes down the drainpipe—out of sight is out of mind! To avoid damaging the environment, wastewater must be treated before it is released into oceans, lakes, and rivers. Most wastewater worldwide is *not* treated, and even treated wastewater can still contain **pollutants**. The scale of the wastewater problem is enormous, and it gets worse each day as the world's population grows. Industrial wastewater is also a concern, because water coming from manufacturing can be contaminated with dangerous chemicals and heavy metals.

WASTEWATER

Water containing pollutants such as human poo and any water that goes down the drain is called wastewater.

POLLUTANTS

Pollutants are unwanted materials found in wastewater like poo, toxic chemicals, and nutrients like nitrogen and phosphorus.

Wastewater treatment plants do a good job of removing most contaminants, but nutrients like phosphorus and nitrogen are not removed. You might wonder why nutrients can be bad, but nutrient pollution can damage oceans, lakes, and rivers. How? The nutrients released into the environment cause lots of **microalgae** to grow in the waterways where wastewater is released. Microalgae are tiny, single-celled plants and, like all plants, they use sunlight to perform photosynthesis and *produce* oxygen. However, when these large masses of algae die, the bacteria that break them down *use up* lots of oxygen. This can lead to vast regions of the world's oceans that have too little oxygen (Figure 1). These areas are called low-oxygen zones, and they can be deadly to the fish and shellfish we eat, along with many other organisms [1]. When some species of algae grow excessively, they can also produce certain chemicals that are toxic to humans and animals.

WASTEWATER TREATMENT PLANTS

Facilities that are designed to remove pollutants from wastewater are called wastewater treatment plants.

MICROALGAE

Microalgae are single cell plants that grow in water using sunlight and/or pollutants.

But what if microalgae could be part of the solution instead of the problem? Specifically, what if these organisms could be used to *improve* wastewater treatment? First, we will tell you about how wastewater is commonly treated, and then we will explain how microalgae can help!

WASTEWATER TREATMENT OVERVIEW

Treatment of wastewater is essential to avoid pollution of lakes, oceans, and rivers (Figure 2). The first step of treatment is screening. Screening removes large particles such as wood, grease, rags, plastic, and gravel. Then comes the removal of smaller, dense particles. This

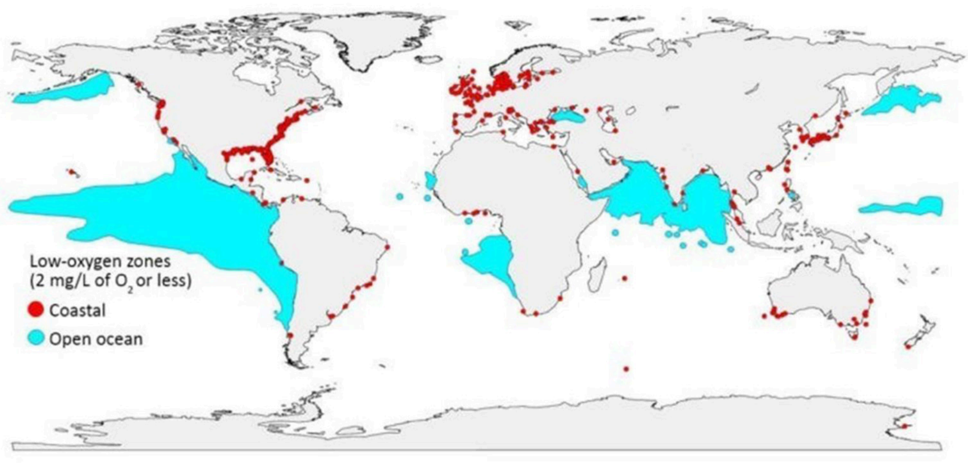

Figure 1

Figure 1

Wastewater pollution results in multiple environmental problems. For example, large regions of the world's oceans can become depleted of oxygen. These regions are called low-oxygen zones. The oxygen concentration of healthy water is 10 milligrams per liter (10 mg/L) and the map shows large areas of oceans, colored blue, and coastal areas near cities, colored red, where the oxygen concentration is much lower. Nutrients from wastewater and from agriculture are the primary cause of oxygen minimum zones. Oxygen measurements are not available for every location on the planet, but this map shows the scope of the problem [1].

is done using gravity—by letting the wastewater sit in large tanks so the particles can settle to the bottom. The wastewater is now ready for the next step of treatment, which normally uses bacteria to remove contaminants from wastewater. How is this possible? Well, the bacteria eat the pollutants and clean up the water. There are several technologies that use bacteria to treat wastewater, and one example is called the activated sludge system, which has been around for over a century. This system contains an aeration tank, where bacteria are supplied with oxygen so they can clean the wastewater in a process called **biodegradation**. Supplying oxygen to bacteria is expensive, and the bacteria still do not eat all the phosphorus and nitrogen. After treatment, the bacteria are separated from the treated water in a settling tank. The third step in wastewater treatment is to kill any remaining bacteria to produce treated wastewater that is released to the environment.

BIODEGRADATION

Bacteria and microalgae can eat many pollutants in a process known as biodegradation.

What about the stubborn pollutants that remain in the water? The water may need further treatments, including filtration, ultraviolet light, and a chemical called ozone, to sterilize it and remove the remaining pollutants—but even these treatments do not sufficiently remove all nutrients.

HOW CAN MICROALGAE IMPROVE WASTEWATER TREATMENT?

Scientists have shown that microalgae can be used to improve the efficiency of the wastewater treatment process. Along with breaking down contaminants, microalgae also produce oxygen, consume carbon dioxide, and remove nutrients like phosphorus and nitrogen from the wastewater more completely than traditional wastewater treatment does. And it is less expensive, too!

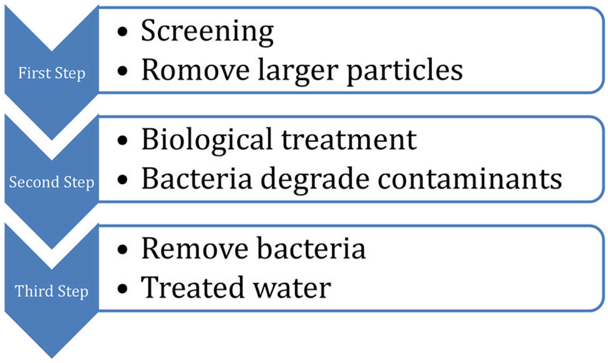

Figure 2

Figure 2

Current wastewater treatment processes. Bacteria are currently used in wastewater treatment, but more complete removal of nutrients could be achieved using microalgae in the second step of treatment. By using microalgae along with bacteria, the excess nutrients normally present in wastewater can be removed. The bacteria and microalgae produced during the treatment of wastewater contain nutrients removed from the wastewater, and can be recycled as fertilizer to help farmers.

BIOMASS

Biomass is renewable organic matter obtained from plants and animals. It holds the stored energy from the sun that plants capture through photosynthesis. Photosynthesis is the process by which plants use sunlight, water, and carbon dioxide to create oxygen and energy in the form of sugar.

BIOFUELS

Microalgae and bacteria can make chemicals that can be used as fuel, such as diesel, ethanol, and methane. Fuels made by microalgae and bacteria are called biofuels.

BIOPLASTICS

Some chemicals made by microalgae and bacteria can be used as substitutes for plastics made from petroleum. Bioplastics are plastic-like materials made by living things.

Even better, the large amounts of algae, called algae **biomass**, grown at wastewater treatment plants could then be used to produce products including **biofuels** (replacements for fossil fuels like gas or oil) and **bioplastics** (replacements for traditional plastics) [2, 3]. The biomass that is leftover could be composted and converted into fertilizer to support farming. This technique basically allows the nutrients removed from wastewater to be recycled.

Production of biofuels from microalgae is usually expensive, with the cost and availability of chemical nutrients, especially phosphorus, being a key limitation [4]. The cost of producing biofuels can be decreased if wastewater is used as a source of nutrients for microalgae. Figure 1 shows that massive amounts of algae *can* grow using nutrients in wastewater [1]. So, instead of releasing nutrients from wastewater into to the environment and creating massive amounts of algae biomass in the oceans, this algae biomass could be created at future wastewater treatment plants that then recycle the nutrients. This technology has not yet been widely used [5], but scientists and engineers could make it happen, and future wastewater treatment plants could instead be called **resource recovery facilities**.

THE FUTURE OF WASTEWATER TREATMENT

To protect the planet, one of the 17 goals set out by the United Nations is to ensure safe water and safe wastewater disposal for all. Making valuable products while effectively treating wastewater is a good way forward! Wastewater treatment technologies of the future will not only produce clean water, but will also capture the precious nutrients, that were in poo, in the form of biomass. Captured biomass can then be used to produce biofuels, bioplastics, and fertilizers.

The conversion of wastewater treatment plants to resource-recovery facilities will be a major challenge requiring technological advances in many fields, including engineering, robotics, biology, chemistry, and public health. Wastewater treatment facilities at universities

RESOURCE RECOVERY FACILITY

An improved wastewater treatment plant that not only cleans wastewater, but also recovers and recycles nutrients is a resource recovery facility.

could provide ideal sites for developing the necessary technologies and could also provide educational and training opportunities. All developed areas on Earth need wastewater treatment. Might your future job be at a resource recovery facility?

ACKNOWLEDGMENTS

The authors acknowledge the value of collaboration to understand and address environmental problems.

REFERENCES

1. Breitburg, D., Levin, L. A., Oschlies, A., Gregoire, M., Garcon, V., Gutierrez, D. et al. 2018. Declining oxygen in the global ocean and coastal waters. *Science* 359:eaam7240. doi: 10.1126/science.aam7240
2. De Mendonca, H. V., Otenio, M. H., Marchao, L.,Lomeu, A., de Souza, D. S., and Reis, A. 2022. Biofuel recovery from microalgae biomass grown in dairy wastewater treated with activated sludge: the next step in sustainable production. *Sci. Tot. Environ.* 824:153838. doi: 10.1016/j.scitotenv.2022.153838
3. Samadhiya, K., Sangtani, R., Nogueira, R., and Bala, K. 2022. Insightful advancement and opportunities for microbial bioplastic production. *Front. Microbiol.* 12:674864. doi: 10.3389/fmicb.2021.674864
4. Kilbane II, J. J. 2021. Shining a light on wastewater treatment with microalgae. *Arab. J. Sci. Eng.* 47:45–56. doi: 10.1007/s13369-021-06444-3
5. Valchev, V., and Ribarova, I. 2022. A review on the reliability and readiness level of microalgae based nutrient recovery technologies for secondary treated effluent in municipal wastewater treatment plants. *Processes* 10:399. doi: 10.3390/pr10020399

SUBMITTED: 17 July 2022; **ACCEPTED:** 10 August 2023;
PUBLISHED ONLINE: 29 August 2023.

EDITOR: Emily King, Xiamen University, China

SCIENCE MENTORS: Manuel Esperon-Rodriguez and Balaji Aglave

CITATION: Kilbane JJ II, Roubik H, Kovacs AJ, Keshinro T, Patel M and Feijter Jd (2023) Poo is Precious. Front. Young Minds 11:996462. doi: 10.3389/frym.2023.996462

CONFLICT OF INTEREST: Author AK was employed by the company KUKK K&F Ltd.

The remaining 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

JOSEPHINE, AGE: 12

My name is Josephine, I am 12 years old and I am in 6th grade. I live with my mom and dad, my four parakeets and a husky. My favorite color is neon-orange, I figure skate, swim, and play golf. I like to read and watch shows about animals, dragons, and mythology. I love animals, but I do not have a favorite since all have different skills and features. I enjoyed working on the article and I hope to do another one.

TANISHKA, AGE: 14

Possessing a strong affinity for science/health, Tanishka enjoys participating in numerous science competitions. She persistently receives 1st fair in STEM Fair and has gotten the Best of Fair award. She has also published two scientific articles in high-impact-factor journals. She is a part of numerous health-science-related clubs such as HOSA and has gotten 1st place at the international level in the HOSA international conference. Tanishka can be found playing her violin or reading whenever not studying or part-taking in competitions.

AUTHORS

JOHN J. KILBANE II

As an environmental microbiologist I have devoted my career to using biotechnology to address environmental issues such as cleaning contaminated soil and water, and the production of biofuels like biomethane, biodiesel, and ethanol. I am a retired Professor from the Illinois Institute of Technology and my current interests are motivating young scientists to improve wastewater treatment using microalgae to produce clean water, recycle nutrients needed by agriculture, and produce sustainable products like bioplastics and biofuels. *john_k61@yahoo.com

HYNEK ROUBIK

Associate Professor Dr. Hynek Roubik is a Group leader of Biogas Research Team (Czech University of Life Sciences Prague). He deals not only with aspects related to biogas, but also with waste management issues in general. He has participated in numerous research and development projects throughout the world as project leader or expert (i.e., Czechia, Vietnam, Cambodia, Ukraine, Uzbekistan, Georgia, Sri Lanka, Indonesia, and others). He does research especially in Waste Management, Environmental and Ecological Engineering, and is an editorial board member of several journals. He is the author of over 50 peer-reviewed (indexed) research papers. He was also appointed as one of the youngest associate professors in Czechia. In his free time, he likes to popularize science and play sports and work in the garden.

ANDRAS J. KOVACS

Emerging from petroleum refinery technology and petrochemisty R&D and teaching I have turned my focus to environmental technologies. I have believe that the best use of algae is their symbiosis with facultative microorganisms. I am confident that young minds will approach problems from multidisciplinary viewpoints on the ground of sound knowledge of mechanisms and connections of systems involved. I am looking forward to receive questions of clever young scientists.

TAOBAT KESHINRO

Taobat is a microbiologist and a lecturer at Lagos State University, Nigeria. She is an early career researcher interested in microbial interactions in natural environment. She is particularly interested in how mutualist relationship between microalgae and bacteria can solve global issues like sustainability, improved sanitation, as well as food and energy production. She is passionate about wastewater treatment, bioremediation, and algal biotechnology. *taobat.keshinro@lasu.edu.ng

MAULIK PATEL

Dr. Maulik Patel working as Post-Doc at USDA facility. He is working on antimicrobials other than antibiotics to mitigate microbial contamination to biorefineries. He has expertise in functional genomics and synthetic biology and agricultural waste liquefaction using enzymatic treatment. He has teaching experience to undergrads and master students at university level and trained many students for biotechnology skills. He also holds entrepreneur expertise in probiotics and developed various strains to be used as spore probiotics for feed animals and biofertilizer. He published various articles covering these topics. He enjoys reading and swimming in his free time, and has a passion for learning new things, application-based research.

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Jacob is a student at Te Wananga o Aotearoa in New Zealand. He is interested in environmental issues and spends his free time racing outrigger canoes and bicycling.