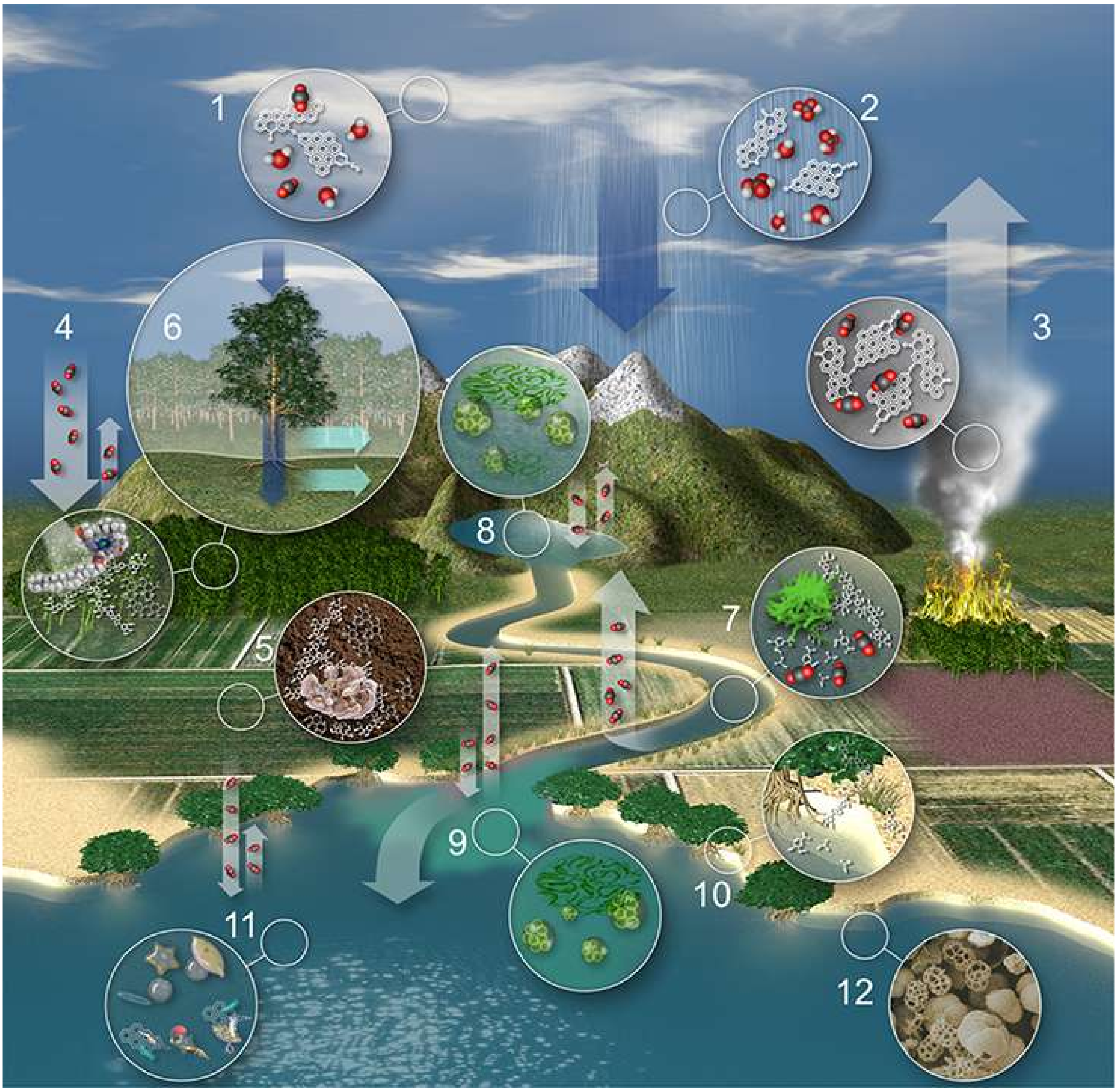
Microbiological Safety And Water Security

Microbiological safety is incredibly important to ensure that diseases and harmful organisms are contained in a secure way. Basically, water is a chemical substance made up of two hydrogen and one oxygen atoms, existing in solid (ice), liquid (water) and gas (water vapour) forms. However, biologically, it is one of the most important constituents of living organisms. Water is a vital component for the survival and existence of all life.

On Earth, water drives the carbon cycle across various spheres, from the atmosphere to the biosphere, bridging aquatic and terrestrial life (Ward et al., 2017). It accounts for 70% or more of total cell mass, it is the most abundant molecule present in a cell. Evidently, water is an active matrix for the sustainability of life, and is essential in our search for the existence of life in the cosmos, particularly, the search for water on MARS and other celestial bodies (Ball, 2017).



Microbiological safety is intricate and delicate: here are atmospheric particles acting as a cloud-condensing nucleus, promoting cloud formation.
Source: Frontiers

Water covers around 75% of the Earth's surface, 96% of which constitutes oceans. Despite vast amounts of water available on Earth, very little is available as fresh water, suitable for human use and other terrestrial life, including plants and animals (Bureau of Reclamation California-Great Basin, 2023). So, in the midst of an ever-expanding human population, why must we endorse and pursue microbiological safety and water security?

What is water security?

Water security refers to the guarantee of the availability of enough water (and the quality of said water) for the survival of all life as we know it. Although water quality can be affected by natural phenomena, human activities under the name of urbanisation and industrialisation now have a major impact on water security. Water pollution has an immeasurable damaging effect on climate change. Now is the time to address this issue promptly. Concurrently, to provide the uninterrupted availability of potable, clean water, and sustainable water management we must prioritise this issue globally. We need to allow nations to be independent, securing enough water for diversified socio-economic sectors (UN Water Security, 2013).

> *"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."*
>
> *UN Water, 2013*

How can microbiological safety mitigate water security?

According to the UN World Water Development Report for 2023, nearly half of the global urban population will face water shortages by 2050 (UNESCO, 2023). Water crises in developing countries are already creating human health emergencies. The presence of hazardous water pollutants, inorganic and organic nutrients and microbial pathogens (including arsenic, nitrates, and heavy metals) are dangerous for human well-being. These water contaminants cause deadly diseases, allergies, and cancer (Hussam, 2013; Wasewar et al., 2020). Population growth, poverty and sub-standard food and water hygiene are playing additional roles in solving the challenges related to water security. 'Thrivability' depends on the way we solve the challenges faced because of such issues.

Remarkably, potable water is the basic survival resource for all life forms. It is the prime duty of any governing body to make sure that its population are provided with an uninterrupted supply of clean and safe water. Water security can be referred to as a policy goal. Conversely, governing bodies have assigned billions of dollars to the National Water Security Policy (Taylor, 2019). United Nations Environment Assembly (UNAE) recognises the necessity to ensure water security and find the solution to challenges we face globally, such as clean water availability. They adopted the resolution in 2017 to address water pollution and to protect and restore water-related ecosystems (UNEP, 2018). Subsequently, in conjunction with the UN, THRIVE's key mission is to identify, research and discover solutions to mitigate sustainability globally, thereby safeguarding human well-being.

Tackling microbiological safety: a global challenge.
Source: UAE Press

the connection between microbiological safety and water security

Microbiological safety is a crucial part of water security. It is the path that leads to the solution to challenges faced in establishing water security. Microbiology provides diagnostic techniques to determine and identify the type of pathogens present in water samples. Treatment for the removal of pathogens can be undertaken according to the results obtained from those techniques. Microbiological analysis is one of the important parts of water quality analysis

(CMDC, 2022).

Concurrently, natural water resources are not free of microorganisms. All of the water bodies that are inclusive of marine and freshwater consist of regular ecological biodiversity. It consists of normal microorganisms and other life forms, thriving as normal residents of that environment. Every organism of that ecological niche contributes to the sustainability of that ecosystem. They have their specific role to play in. Healthy freshwater ecosystems have their own plethora of microorganisms. They contain diversified microbes that include bacteria, algae, fungi and protists. Microbiomes are the primary participants in regulating biogeochemical cycles occurring in aquatic environments. Furthermore, they possess the surprising potential to metabolise myriads of components present in water and other environments (Ren et al., 2019).

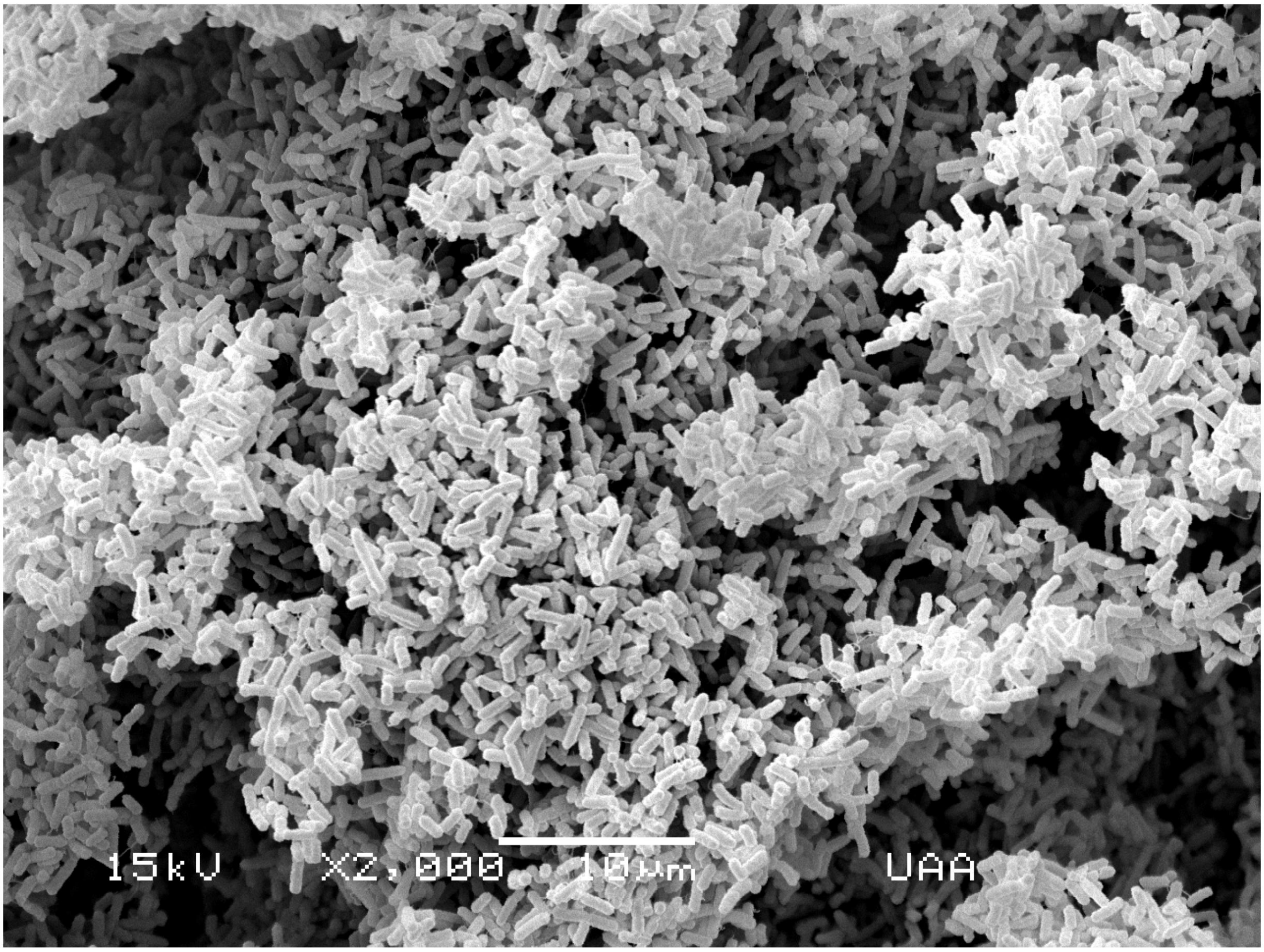
Microbes in Natural Water Resources

Algae and other photosynthetic microorganisms, popularly known as phytoplankton, trap atmospheric inorganic CO^2. Microalgal species, mainly, Chlorophyta (green algae), Euglenoids, Dinoflagellates, Diatoms, Rhodophyta, Brown algae and many others, are eukaryotic photosynthetic microorganisms that can rapidly grow in harsh conditions (Sharma et al., 2019). Cyanobacteria, popularly known as blue-green algae, are procaryotic photosynthetic bacteria that dominate the group of CO^2-fixing microorganisms in water ecosystems. They convert inorganic carbon (CO^2) into utilisable organic carbon molecules such as lipids, carbohydrates and proteins. These molecules are consumed as nutrients by saprophytic microorganisms for their growth and metabolism. They trap significant amounts of carbon in their cellular bodies, maintaining a dissolved oxygen level (or 'DO level') in the water resources.

Next comes the role of bacteria and other non-photosynthetic microbes. Evidently, major types of bacteria found in aquatic environments are saprophytic, surviving on dead organic nutrients and hence are non-pathogenic. Members of bacteria generate Micrococcus, Pseudomonas, Serratia, Flavobacterium, Chromobacterium, Acinetobacter, and Alcaligenes, dominant in the water microbiome community. Consequently, these saprophytes play a crucial role in the carbon cycle occurring in the freshwater ecosystem. Even though bacteria dominate in freshwater ecosystems, fungal communities also form a major share in the microbial communities of waterbodies. The PLOS ONE Journal studied saprophytic freshwater fungal communities and found that fungi of phyla Ascomycota, Basidiomycota, Chytridiomycota, and Cryptomycota were prevalent in up 49 per cent.

Pathogens in water

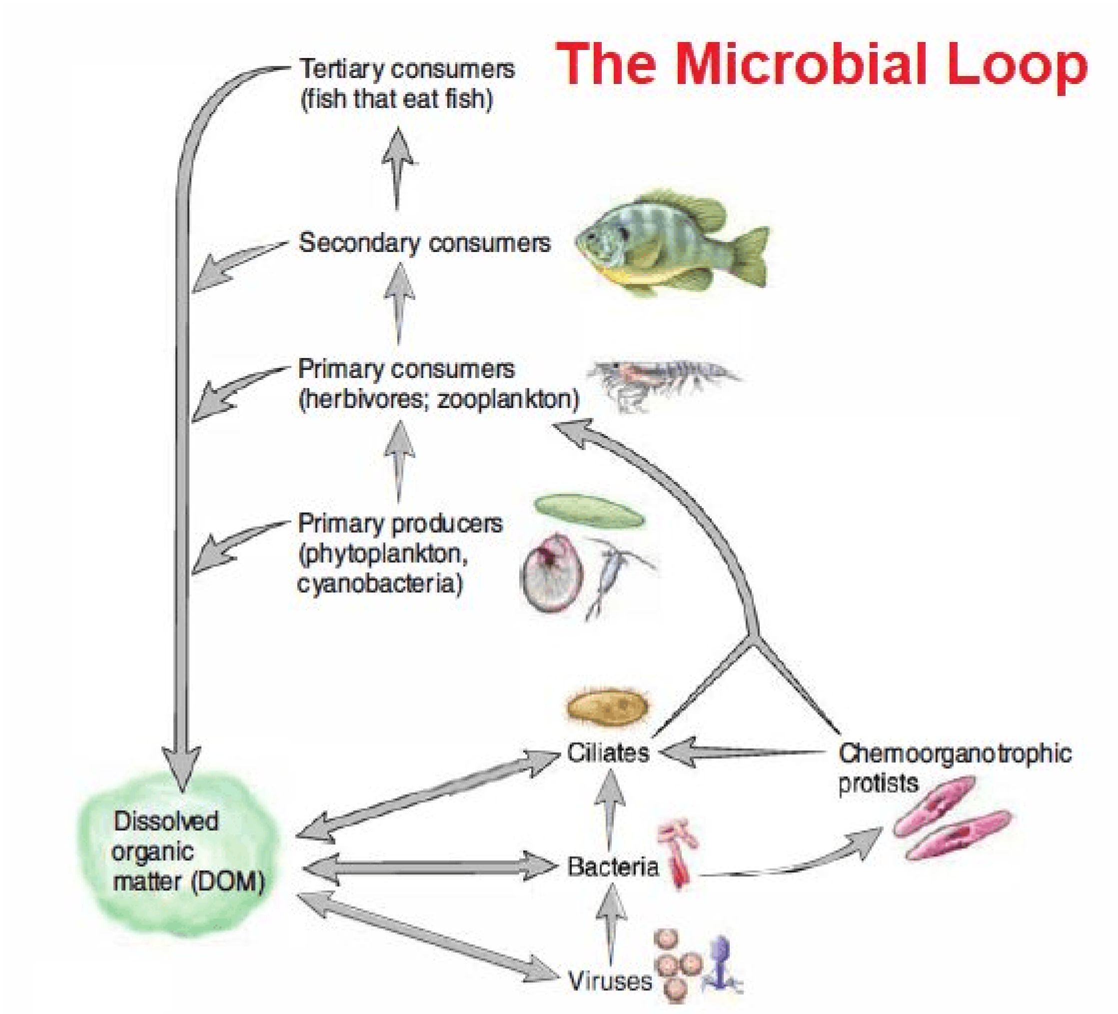
Although industrialisation and urbanisation are essential for development, they are prime reasons for slumping water quality. Industrial effluents, drainage effluents, and untreated sewage discharged into water bodies cause irreparable damage to water quality. Significantly, they are the sources of inorganic and organic pollutants as well as pathogenic microorganisms. Consequently, if entered (untreated), drainage water and domestic sewage can lead to serious consequences that affect human health. Fecal contamination of water allows entry of pathogenic bacteria, viruses, protozoa and parasitic worms. Contaminated drinking water may consist of pathogenic bacteria (Salmonella, E. coli, Vibrio, and Shigella), viruses (such as Norwalk virus and rotaviruses), and protozoans (such as Entamoeba, Giardia, and Cryptosporidium) (Castillo et al., 2015).



Scanning electron micrograph of E. coli isolated from river water, part of the mitigation of microbiological safety.
Source: Pathogens

why Is it essential that we focus on Microbiological safety and water security?

Flora and fauna of water bodies are the biological indicators of the water quality index (Department of Environment & Science, 2019). Microorganisms form a microbial loop in the food chain of aquatic ecosystems (Kumar, 2019). In turn, microbes tend to break down larger nutrients into smaller, dissolved, organic substances which form the Dissolved Organic Matter (DOM) in the water; an essential part of the microbial loop. These smaller nutrients are a major source of nutrients for other organisms thriving in these ecosystems. DOM forms a key portion of the food web of aquatic ecosystems- a crucial stage that contributes to the carbon cycle. Moreover, microbes also play a crucial role in degrading the dead bodies of aquatic animals. Microbiomes are the key participants in maintaining the ecological balance and water quality of any aquatic ecosystem (Geological Survey Circular, 1974).



The Microbial Loop.
Source: Microbiology Notes

Human activities under the title of socio-economic development have now resulted in climate change. This has altered the ecological balance of the freshwater ecosystem along with affecting the biodiversity of nature. If these conditions prevail, normal flora and fauna in our water will be affected. Consequently, this will lead to the deterioration of the water quality of freshwater resources, rendering them non-potable and unsafe for human consumption. Dramatic population rises, mainly in developing countries, and unregulated anthropogenic activities have made complete water treatment difficult. This has a high impact on water sanitation, leading to threatening situations for human health (WHO, 2022). Organisations such as THRIVE have been directing attention to these concerns. However, prompt actions are required to fight against these challenges. Microbiological safety can provide multiple alternatives towards maintaining water quality.

Microbiology & Water borne diseases

Conversely, diagnostic microbiological techniques help in testing fecal contamination of freshwater resources and identifying the type of pathogens present in water. Significantly, this can protect the human population from waterborne diseases. Over 95% of waterborne diseases are preventable, and their elimination represents specific Millennium Goal targets (Griffiths J., 2008). Searches for and identification of every pathogen present in water are impractical. Detection of the bacteria that are indicative of fecal pollution seems to be a feasible and faster means of water quality analysis (BOBP For Fisheries Management, 1999).

Coliforms (E.coli) are indicator organisms for fecal contamination. Indicator bacteria E. coli and Intestinal enterococci should not be present in 100 mL of water volume (Commission directive, 2015). They are detected by culture-dependent methods such as the Multiple Tube Fermentation (MTF) techniques of the Membrane filtration technique. Additionally, there are molecular methods such as PCR, Microarray, and many others, used for detecting low concentrations of specific pathogens (Castillo et al., 2015).

Microbiology & Wastewater treatment

Microorganisms are frontline players in effluent treatment plants. They have a tendency to form biofilms and collaboratively degrade the pollutants present in the wastewater. Members of this biofilm metabolise water pollutants for their growth. These members convert them into non-hazardous forms through the process known as bioremediation (Agarwal M., 2015). They participate in clearing the suspended solids present in the water, making it clearer and suitable for discharging into the environment. Two extensively used microbial-based sewage treatment designs are Trickling Filters and Activated Sludge Processes. These setups utilise the capacity of microbes to break down raw sewage.

To conclude, Aerobic digestion by trillions of aerobic bacteria is the preliminary treatment of wastewater. They use oxygen and convert harmful organic matter into a less hazardous form. Anaerobic digestion involves the fermentation of organic matter present in wastewater by microorganisms. Anaerobic microorganisms convert organic matter into biogas (NCH, 2017). They eliminate the sewage by trapping it in the form of their cellular biomass, as they grow and reproduce. This results in improving the water properties such as increased DO level, reduction in suspended solids, and reduced BOD-COD, before it is released into rivers (Wastewater treatment, 2023).

Wastewater can be detrimental to the environment if left untreated.
Source: AOS Treatment Solutions

achieving the United Nations Sustainability Development Goals (SDGs)

Microbiological safety is essential, and water is an arbitrator in achieving sustainability. The UN has recognised clean water and sanitation as one of the Sustainable Development Goals (SDGs). It has indicated the direct impact of greenhouse gas emissions in relation to water quality improvement. It has suggested the restoration of wetlands and has recognised the contribution of in-house microorganisms for water purification in wetlands. All frontline countries of the world joined hands in 2023 during the UN Water Conference convened by UN General Assembly. Members recognised the need for prompt measures across diverse sectors involving health, industries and infrastructure and all other sectors (UN Water Action Agenda, 2023). The availability of pathogen-free potable water is the prime concern encompassing multiple SDGs directly.

A Thrivable Framework

THRIVE Project is committed to working in line with the SDGs of the United Nations. We, as a THRIVE community, are working diligently to bring awareness among the population and policymakers, to increase understanding of the need for sustainable processes, including water security.

Individuals have started identifying the importance of the uninterrupted availability of clean water for a good life. Policymakers and industrial designers have started recognising the potential of microorganisms to solve water security. Microorganisms are now employed in green technologies for water management, water treatments, and other related sustainable process developments in multiple sectors. There are still large percentages of microbial technologies to be explored in the quest for sustainability.

THRIVE Framework is continuously mitigating solutions geared towards environmental, social and economic sustainability through its diversified activities, involving webinars, blogs and an extensive podcast series. THRIVE invests in diversified activities engulfing meaningful global issues that include science, innovation, sustainability, society, human rights, world events and microbiological safety. Our newsletter endeavours to spread awareness about 'Thrivability' ahead of sustainability. Sign up for our newsletter for regular updates on issues that concern us all.