MITIGATION STRATEGIES FOR DROUGHT

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BRIEF OVERVIEW

Drought as a form of natural disaster has become a persistent part of everyday life, thanks to global heating and the climate crisis.

Worldwide, multiple regions are facing unprecedented agricultural, meteorological and hydrological droughts which have massive socio-economic impacts. Drought is responsible for over 15 % all natural disaster losses every year.

Geographically, the highest prevalence of drought is in Sub-Saharan Africa, followed by central and South America, southern Europe, the Middle East and southern Australia (Millenium drought since mid-1990s, 1997-2009).

Beyond these locations, fully half of the global population which faces severe water crises live in India and China.

Megacities across Brazil and in Cape Town, South Africa, have already faced their Day Zero when the city water supplies were turned off, forcing businesses to shut down. In the summer of 2019, 6 of the largest metropolitan areas in India were without water for many weeks, forcing rationing of potable water to 1.5 liters per person per week.

By the end of 21st century, the climate projections suggest severe drought to take over everyday life in Europe, with serious implications on its socio-economic setup. The business-as-usual scenario demands for climate change mitigation will drastically increase both severity and duration of summer droughts in Europe.

The unprecedented heat waves which are becoming the new normal in United States are conducive for having created what climatologists say are the worst that region has experienced in over 1200 years.

The intensity of hydrological droughts is such that the water levels in the largest water reservoirs can no longer support 100% operation of the hydroelectric power plants, putting significant exertions on energy grid. The over-exploitation of freshwater reservoirs that are already depleting due to changing precipitation patterns and low winter snow packs will not be an option to meet the conflicting demands for domestic, agriculture and electricity generation. By 2040, business as usual for power generation using water will have catastrophic effects on demands and supply of electricity, water or both.

Due to climate change, the increasing needs for irrigation water will further elevate agriculture droughts in most parts of the world. Shortages in water availability due to increasing human populations, growing livestock production, intensive agriculture and consumerism, in addition to from climate change itself, will profoundly endanger the food supply worldwide particularly in drought-prone regions in the continent of Africa.

Therefore, more is needed than just a patchwork approach to address this State of Emergency to tackle droughts and water shortages in the light of the fact that climate change will only worsen the global water crisis.

The prolonged nature and depth of global drought and desertification demands a customized response and a willingness to change.

Although drought and desertification are being exacerbated by global heating, the prolonged drought requires response customized for individual situations and a willingness to adapt.

For those having to deal with worsening drought, mitigation is just one of three pillars of a fully developed approach to handling the situation. A second is a thorough analysis of vulnerabilities to drought and risk assessment. A third is to have accurate means of projecting future droughts, both macro and micro, including early warning systems to flag problems long before they become critical.

As the exceptional lack of water compared with normal conditions is the main hazard pose by drought, we must address the planetary crisis of 'water wars' by rerouting towards implementation of global mitigation solutions and adoption of 'cradle-to cradle' approach towards building a drought resilient society.

In this paper, we have discussed the ways in which we can utilize wastewater and adopt it as universal mitigation strategy that not only protect our freshwater resources against contamination but also restore pastures and balance the land and water resources.

Climate Survival Solutions accepts global water scarcity as a paramount challenge to continually achieve the sustainability goals to tackle climate crisis. Water is a precious resource needed to support a wide range of sectors, encompassing energy, food supply, transportation, and goods manufacturing.

Water is also traded across the globe in forms of agriculture, raw materials, and industrial goods. It is for this reason that regional impacts on water supply in one area will have a ripple effect globally across economic sectors. Therefore, alternative solutions are required to mitigate the impacts in all economic sectors that rely on water resource.

In this paper, we have discussed how the wastewater that is generated by all sectors can be transformed into a renewable and alternative resource for mitigating impacts of water scarcity and drought.

INTRODUCTION

Numerous scientific studies, research reports and meteorological surveys have shown us the dire situation of water scarcity, water stress or drought on a global range. According to UN Meteorological Organization the climate crisis will leave over half the world's population without enough potable water by 2050. That means one out of every two people on the planet will not have access to enough fresh water to survive.

Several reasons account for the water scarcity, including inadequate water management, poor infrastructure, natural disasters and climate change. The water abstraction rate is higher than the rate at which water could replenish in our freshwater aquifers. The water deficits due to increasing rates of withdrawal in both developed and developing countries will put two-thirds of the global population at risk of water shortages (Pal 2017). This will consequently lead to 'water-wars' and socio-political conflicts.

More than half of rivers worldwide are already flowing at reduced stream flows (Albert, et al. 2021). Over exploitation of aquifers due to rapid urbanization, polluted domestic and industrial effluents in rivers, sewage seepage and intensified groundwater abstraction, ecosystem degradation, outdated infrastructure, salinity intrusion, in-efficient no user charges based water use policies, climate change and drought are the main factors responsible for water crisis (Ghosh and Ghosh 2021).

The three major sectors of the economy that use the largest amounts of water are agriculture, domestic and industry. Of these, agriculture is responsible for around 80% of total water usage worldwide.

Globally, water demand is expected to increase significantly in the coming years. Although, industrial water usage is less than that required in agriculture, the grey water footprint is comparatively higher for industrial sector. For instance, the industrialised nations of Europe, where despite their apparent share of agriculture water abstraction being the least among the continents, also have huge virtual water footprints due to import of million ton of agriculture goods from all over the globe. Some of these water intensive commodities include cotton, nuts, rice, coffee and other food crops which are being produced in the water stressed countries. In fact, the highest share of EU's external water footprint takes place outside its border, mainly in US, Pakistan, Turkey, Egypt and India. Also of interest, the largest net exporters of virtual water are North and South America, South Asia and Australia.

Fluctuations in rainfall and drought are recurring phenomenon around the globe are causing millions of people to suffer from long term chronic food insecurity, particularly in drought prone regions of Africa. Therefore, water shortages in any part of the world would endanger the global supply of various kinds of agriculture goods namely food, feed and fuel.

Water is also increasingly becoming scarce in the Western US where more than 70% region is in severe drought and above 20% drought conditions are exceptional. With climate change and global warming being the main reasons for insufficient summer rains and low snowpack over winters; the past decades have been the driest in last 1,200 years questioning the livable future in the southwest US. The lake reservoirs from the region's biggest river are merely 30 % of its capacity than it had a century ago.

In less developed nations such as Africa, Asia and Latin America, the poor wastewater management is causing the river streams to get severely polluted with organic contaminants resulting into a high concentration of biological oxygen demand. This greatly impacts their ecosystems and its functioning which in turn has a global impact on the planet. Asia and Latin America, which abstract vast quantities of blue waters for supporting their agriculture sector, release huge amounts of nutrients and agrochemicals which cause increasing anthropogenic loads of phosphorous in some of the largest lakes in Africa and Latin America.

In contrast, Latin America and the Caribbean, which are exporting over billion cubic meters of virtual water per year all across the globe have a negligible share of wastewater being treated and reused compared to their high income counterparts. It is neither sustainable nor hospitable for the planet to export water intensive traded products such as coffee, sugar, wheat, soybean, oil seeds, cotton and livestock products vast amounts of virtual waters from low income to the high income countries which comparatively have more efficient and advanced wastewater management. Therefore, to address this planetary crisis for water, food, animal feed and energy, we must adopt a global path to provide adequate water supplies to everyone. This calls for global cooperation in data analysis, forecasting, and alternative solutions.

Our organisation focuses on finding the sustainable and environmental friendly solutions that can mitigate the planetary water crisis by treating wastewater as a resource rather than a nuisance to recover various resources. The potent treatment of waste for safe and eco-friendly discharge is already well-established, which moves us to the need to upgrade the sustainability performance of these technologies by incorporating efficient resource recovery technologies.

The mushrooming human and livestock populations of the future will impact the market supply potential for water, energy, natural gas, fertilizers, feed, organic compounds and industrial CO2. Therefore, nationwide wastewater schemes including potable demand has to be implemented globally.

With severe droughts and rising populations, we will also have to accept the “toilet-to-tap” schemes. The wastewater that flows down the drain can be filtered and treated until it is as pure as spring water. Spurred by drought and growing populations, many cities are already incorporating recycled wastewater into the water supply. Not only is recycling becoming a necessity, a sustainable water future will demand it. Without an doubt, we all will be drinking the recycled wastewater in future. Wastewater is an untapped resource and its plentiful availability makes it as a cheaper and guaranteed resource.

DROUGHT: A PLANETARY CRISIS

Global water resources

About 96.5% of the total water on the surface of the earth forms the saline water found in oceans. Only an estimated 2.53% of surface waters is freshwater, out of which 70% is blocked in the glaciers and the remaining water occurs as the soil moisture, or in deep aquifers. Thereby, only a meagre portion of about 1% is available as the direct water utilized for human consumption Figure 1). The small available portion is constantly stressed due to the ever-increasing population and the climate crisis.

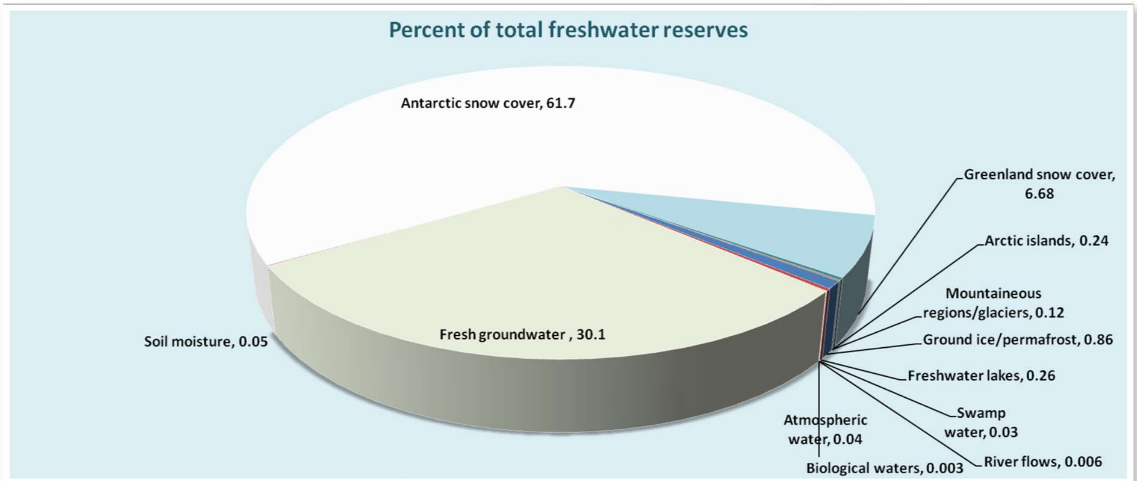

Figure 1. Distribution of global freshwater resources. Data sourced from (Shiklomanov 1990).

Box 1. Crucial facts about water as a renewable resource.

- **The atmospheric water stock is regenerated about every 10 days.**
- **Average regeneration time of a river is 16 days**
- **Renewal periods of the glaciers, groundwater, ocean and large lakes are 100s to 1000s years**

Source: (Meran, Siehlow and Hirschhausen 2021)

Factors responsible for water scarcity and drought

Numerous scientific studies, research reports and meteorological surveys have shown us the dire situation of water scarcity, water stress or drought on a global range.

Inadequate water management, poor infrastructure, natural disasters and climate change are major reasons for worldwide water shortages. Due to poor wastewater management, the river streams across Africa, Asia and Latin America have become severely polluted with organic contaminants, making for a concentration of waterways with high biological oxygen demand.

This greatly impacts the ecosystems and its functioning. Asia and Latin America which abstract vast quantities of blue waters for supporting their agriculture sector also release huge amounts of nutrients and agrochemical. Those in turn cause increasing anthropogenic loads of phosphorous in some of the largest lakes in Africa and Latin America.

We humans are continuing to explode in numbers, and our changing food habits with increased demand for livestock production, puts undue pressure on agriculture sector which is already causing environmental damages due to intensive irrigation practices and enhanced fertilizer usages.

As a result, agriculture runoffs laden with nutrients, harmful pesticides and insecticides generate massive grey water footprints. Thus, shortages in water availability due to increasing human populations, growing livestock production, intensive agriculture and climate change would not only affect our freshwater supplies but will also endanger the food supply worldwide.

Drought and desertification are being exacerbated by climate change. Prolonged drought requires appropriate response and willingness to adapt. The Drought mitigation measures are one of the three key pillars for enhancing drought resilience which we have covered in detail in our proceeding paper. The utilization of wastewater as mitigation strategy not only protects the water sources against contamination but also restores pastures and balance the land and water resources.

Various sectors of economy impacted by drought

Water scarcity is a serious issue which affects every sector of the economy and is an emerging world crisis. There is robust evidence with high agreement that climate change will have drastic impact on the water supply infrastructure, water demand and water dependent energy generation and technological processes (Arent, et al. 2014). Water scarcity will make it imperative for businesses to relocate to places with easy access to freshwater sources such as rivers and lakes in order to expand and keep their workforce. As businesses need water to operate, relocation is not a sustainable option as it has domino effects on the local communities, commerce, incomes and social activities. In addition it represents non-equitable short term solution for firms based in high income countries of the world.

The key economic implication of water scarcity and drought is decreasing agricultural yields and production as this sector accounts for around 80% of total water consumption. Agriculture is highly dependent on water resources and thus waning water supplies not only deteriorates the quality of land but also degrades the ecosystems. Agriculture produce are primary source of global water consumption which are the most traded and dominate the foreign instead of local markets. Therefore, the impacts of drought in local agriculture wobble globally (Dolan, et al. 2021).

Both rain fed and irrigated agriculture is directly affected by the drought which also directly and indirectly impact livestock and dairy and food processing industries respectively.The food, chemical, paper, petrochemical refinery and energy sectors must recycle and reuse the water efficiently to overcome the dire impacts of hydrological, meteorological and agriculture drought. Forestry is one of the examples that explain the impacts of hydrological and meteorological drought. Forest-based industries such as paper and pulp rely heavily on both green (precipitation) and blue (freshwater resources) waters. For example, the paper is made from different types of wood pulp from trees growing in varied biomes of the world that have massive water footprints as presented in the Figure 2.

The ways in which industries can focus on water saving are financial incentives from governments and by undertaking water use or water footprint assessments representing their blue and grey water footprints. The most sustainable approach to lower the impact of industries on water resources is creating circular routes of economy (Sauv´e, Lamontagne, Dupras, & Stahel, 2021) by treating and reusing grey or polluted waters. The tertiary treated waste water where the raw industrial effluents reach the level of environmental acceptance can eventually be reused as means of irrigation (Lahlou, Mackey, & Al-Ansari, 2021).

Global water scarcity and drought will have serious consequences on the availability of clean drinking water to a large segment of the population. For instance, 50% of human populations will be water stressed in coming years, with 785 million people failing to get basic drinking water service, including 144 million people that rely on surface water. Cross border water conflicts are fast approaching with several water-stressed cities around the globe importing water from long distances to the place where it is most required at high cost. To overcome the high costs involved in water transport and associated ecological damage, it is imperative to seek alternatives to provide safe drinking water at or near the consumption point.

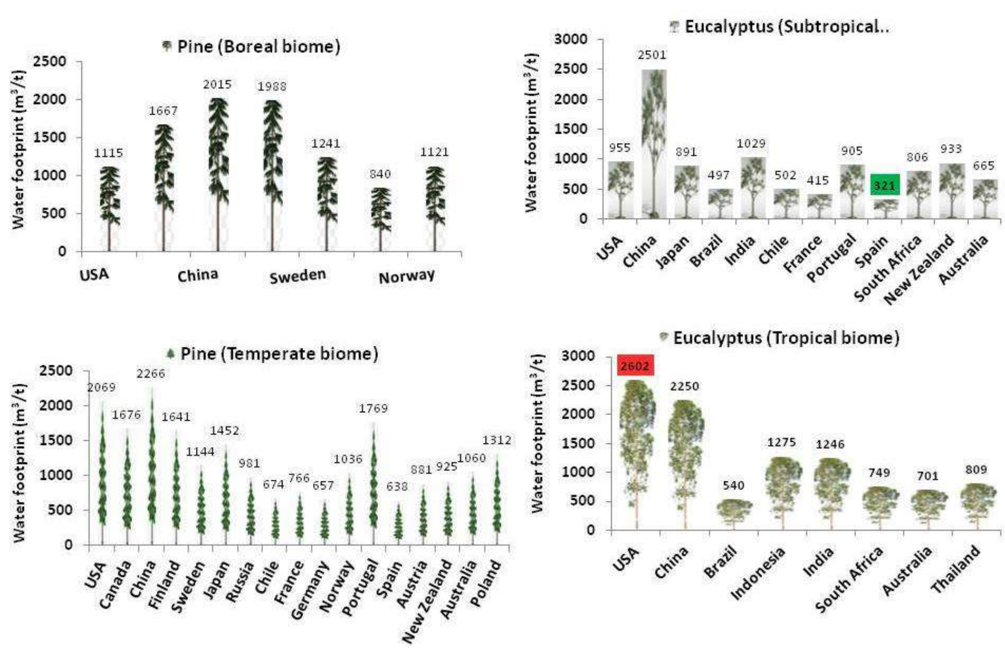

Figure 2: Tree type and country specific water footprint of 'printing and writing paper' derived. Data source: (Van Oel and Hoekstra 2012).

Global wastewater production

An estimated amount of global annual wastewater production is 359.4×10^9 m³ yr⁻¹ of which 63% wastewater is collected and only 52% is being on global scale. In addition, only 40.7×10^9 $m^3\ yr^{-1}$ of wastewater that is produced globally (approximately 11%) is being reused indicating that vast amounts of secondary treated wastewater is simply discharged into the environment (Jones, et al. 2021).

The wastewater production per capita (Figure 3) and treatment rate (Figure 4) are lower in developing countries. Depending on the level of economic development, the wastewater reuse varies substantially across different countries (Figure 5). The intentional untreated reuse of wastewater is also prevalent in lower-middle and low-income countries (Jones, et al. 2021). The main drivers for wastewater treatment and reuse are social, economic, geographical, and hydrological and availability of data (Jones, et al. 2021).

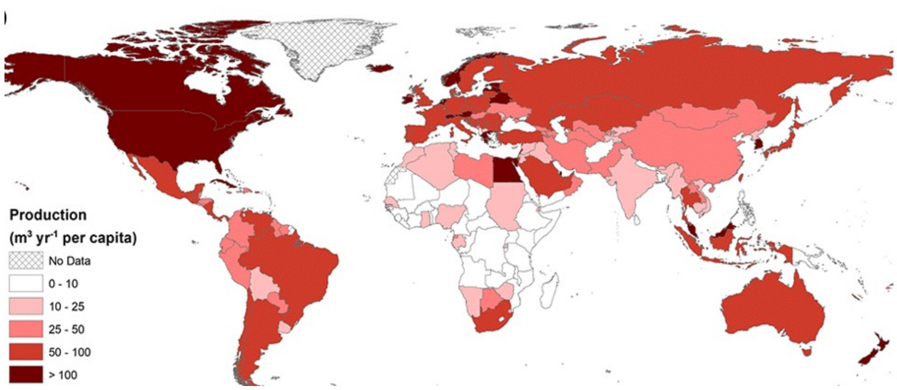

Figure 3. Global wastewater production. Image modified from (Jones, et al. 2021).

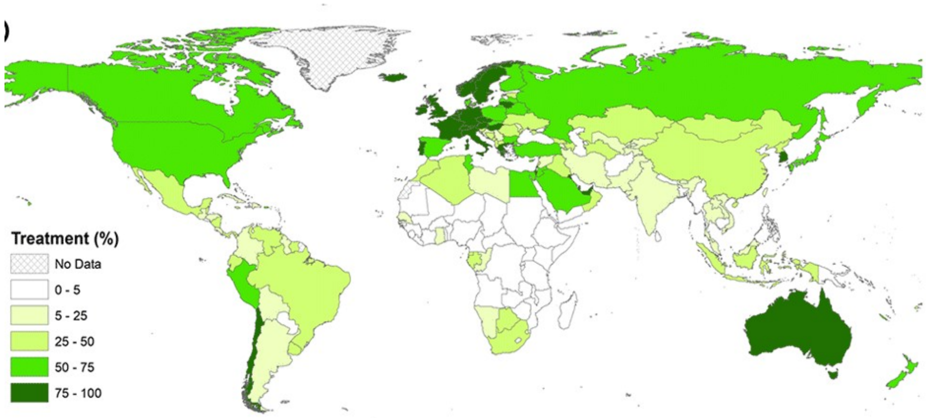

Figure 4. Country scale treatment of wastewater produced. Image modified from (Jones, et al. 2021).

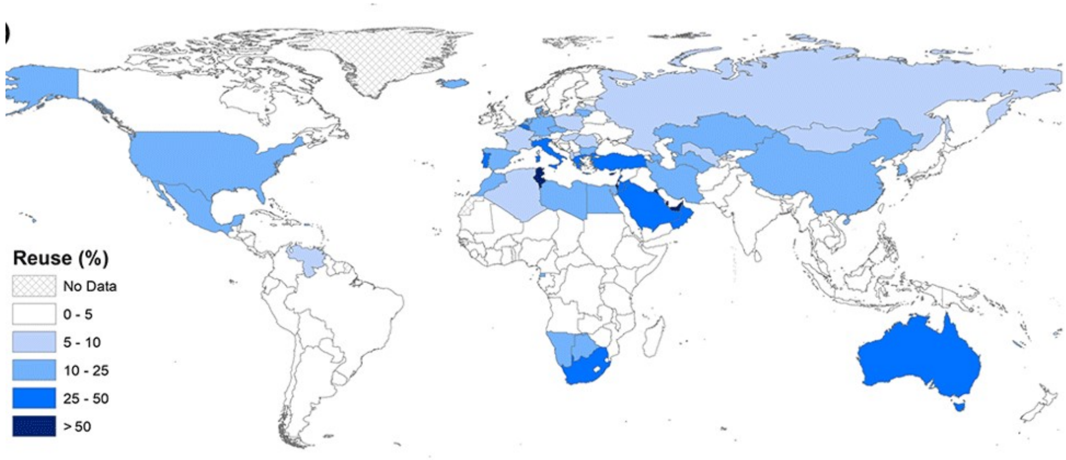

Figure 5. Country scale reuse of treated wastewater. Image modified from (Jones, et al. 2021).

CRADLE TO CRADLE APPROACH FOR DROUGHT MANAGEMENT

Wastewater management via conversion and transformation

Biotechnological interventions and solutions

Bio-based technologies are among the most popular and promising solution categories to various socio-economic crises such as water scarcity and drought. The biological interventions help to achieve accessibility to potable water and carbon-neutral energy. These are best contenders for attaining sustainable development goals by establishing a circular bioeconomy.

Wastewaters provide a rich source of organic and inorganic nutrients such as carbon, nitrogen, phosphorous and potential energy. The use of prokaryotic and eukaryotic microorganisms and their consortia provide potential benefits of improving nutrient recovery efficiencies with simultaneous production of biomass rich in revenue generating bio-products.

The potential benefits of biomass production, nutrient recovery, renewable biofuel generation and fixation of atmospheric CO_2 represent a win-win situation in sustainable economic development.

Conventional solutions based on prokaryotic life forms

Prokaryotic life forms such as anaerobic bacteria and microbes treat wastewater to generate bio energy in the form of biogas via process of anaerobic digestion. Biogas is generated by the anaerobic digestion of organic matter such as sewage sludge, animals, and municipal waste. Biogas forms a vital source of energy in heat and electricity generation along with being the worthiest renewable source of energy globally. It comprises of methane (55-60%), carbon dioxide (35-40%), hydrogen (2-7%) hydrogen sulphide (2%), ammonia (0-0.05 %) and nitrogen (0-2%). The methane undergoes a scrubbing process to remove other gases to obtain pure methane. This methane gas then passes through a fuel cell to produce electricity and is also used as the source of energy for heating purposes. The production of biogas from the wastewater fills in the gap created between the demand and supply of electricity due to droughts. Likewise, it is clean, green energy which is widely used in many parts of the world.

Advanced biotechnological approaches

Microbial Fuel Cells (MFC) can serve as an innovative technique to reuse the wastewater to generate electricity to offset the pressure on the energy grid and compensate for the loss of hydroelectricity due to droughts.

In principle, MFC involves uutilization of catalytic mechanism of microbes for conversion of stored energy in chemical bonds of organic and inorganic compounds to electrical energy through redox reaction where electrons are transferred to a terminal electron acceptor to generate electricity (Agrawal, et al. 2019).

MFC comprises of anode (in an anaerobic environment) and cathode (in the aerobic environment) separated by a cationic selective membrane and linked together with an external conductor through a load. The input of organic fuel, i.e. the wastewater into the anodic chamber (comprising of microbes) results in oxidation of the substrate by microbes to generate ATP that fuels the cellular machinery forming electrons, protons, and carbon dioxide as the by-products. The electrons produced pass from the anode to the cathode through an external load connection, generating an electric current. At the same time, the protons migrate to the cathode chamber from the anode chamber freely through the protonic selective membrane separating the two chambers. The reactions occurring at anode and cathode are, as mentioned using a typical example of acetate as a substrate and is as mentioned:

Anode reaction: $CH_3COO^- + H_2O \xrightarrow[\text{Anaerobic environment}]{\text{Microbes}} 2CO_2 + 7H^+ + 8e^-$

Cathode reaction: $2O_2 + 8e^- + 8H^+ \longrightarrow 4H_2O$

Overall reaction: $CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O + \text{Electricity}$

Wastewater circular bio economy

An obligation under Sustainable Development Goal 6 in the 2030 sustainable development agenda of the United Nations, countries must reduce their grey water footprint to ensure safe clean water and sanitation (U.N. 2020). An alternative approach is to develop biorefinery solutions, which convert wastewater to economically valuable resources and support various sectors of the economy. From a biotechnological perspective, various types of micro and macro organisms such as bacteria, fungi, algae and plants are exploited in the biological water reclamation processes with co-production of renewable bio energy and bioproducts. The conversion of the organic and inorganic nutrients present in wastewater into biomass presents the best option of circular economy in which raw material and final products are obtained from within the same process cycle.

When exploited sustainably, biomass is a renewable resource, allowing for effectively processing each of its constituents individually to produce different kinds of products is defined as biorefinery. When the biomass is derived via water treatment and reclamation process plant, it is called waste water biorefinery. Important considerations during the setting up of waste water biorefinery include the composition and complexities of the waste waters and the market assessment for the co-products recovered from the refinery (Kusch-Brandt and Alsheyab 2021). For example, the baker's yeast wastewater or the vinasse has very high chemical oxygen demand (COD) of 29,000 mg/l with acidic pH of 4-5 is a cost effective substrate for fermentation growth of the protein rich filamentous fungi which is subsequently grown with suitable bacteria for further breakdown of organic nutrients via anaerobic digestion. Thus in a two step waste water biorefinery process, the chemical oxygen demand is lowered with co-production of protein rich biomass and methane rich biogas (Hashemi, Keikhosro and Taherzadeh 2021).

Municipality wastewater which has low chemical oxygen demand (COD) values such as 250-290 mg/l are used in alternative technology of agriculture irrigation for non-food crops called phyto-filtration. Depending upon the geographical regions, various such crops can be selected that have low nutrient requirement, grow faster and produce valuable co-products. For instance, willow plantations in Quebec, Canada when irrigated with primary effluent municipal wastewater with COD of 290.3 mg/l and pH 7.1 for phyto-filtration treatment process also resulted in better yields of willow trees with biomass rich in glucose, lignin and diverse phytochemicals (Sas, et al. 2021). The exploitation of photosynthetic organisms such as microalga is widely chosen for phosphate removal and co-production of multiple bioproducts.

In comparison to other micro and macro organisms, the microalgae approaches present unique characteristics such as a) their abilities to drive nutrition via photo-, hetero- and mixo-trophically b) pollutant scavanging c) CO2 assimilation and sequestration d) synergistic growth with bacteria e) production of numerous bioproducts. Due to these advantages, microalgae can be simultaneously exploited for treating wastewater from industries, agriculture and muncipalities along with the co-production of industrial products. On the other hand, the commercial production or microalgae farming have several constraints, such as high production cost, nutrient requirement which has high environment footprint, water scarcity and need for phosphorous which is a non-renewable resource (Delrue, et al. 2016). Therefore, wastewater becomes a necessity for sustainable and economical farming of microalgae. Thus, the 'marriage' of microalgae and wastewater treatment is inevitable.

Bioremediation using microalgae

Microalgae have a high tolerance to nutrients and salt stresses (Catone, et al. 2021). Microalgae uptake inorganic nutrients from industrial, agricultural and domestic wastewaters in the form of nitrates, ammonium, phosphates, potassium, etc for their growth and conversion to biomass. In addition, microalgae are also known to incorporate and disintegrate several forms of micropollutants such as Pharmaceutical and Personal Care Products (PPCP), Endocrine Disrupting Compounds (EDC) and heavy metals (Delrue, et al. 2016) as they possess catabolic genes for degrading pollutants (Subashchandrabose, et al. 2013). Some conventional treatment plants are inefficient to tackle the problem of micropollutants; therefore, microlage present an alternative method of treatment of these harmful and toxic chemicals. Being ubiquotous in nature, microlage including blue green algae or the cyanobacteria can thrive in variety of diverse habitats and niches which present a plethora of bioresource wealth that can be exploited for diverse forms of wastewater sources. The bacteria and fungi led breakdown of organic pollutants is disadvantageous due to associated increase in the atmospheric carbon pool (Subashchandrabose, et al. 2013).

The ability of microalgae to grow hetero and mixotrphically make them suitable candidates for treating wastewaters with phenolic compounds as algae grown under this mode of nutrition can reduce the toxicity of these pollutants. For examples, the microalga *Ocromonas danica* possess metabolic pathway that can catabolise phenol to pyruvate and CO_2; miccroalgae namely *Ankistrodesmus braunii* and *Scenedesmus quadriquada* can degrade various forms of phenolic compounds by 70%, the green microlage *Chlorella vulgaris* photodegraded an endocrine disruptor phenolic compound called Bisphenol. Algae can also convert toxic pollutants to non-toxic (Subashchandrabose, et al. 2013).

Waste water treatment and co-production of industrial products by microalgae

Microalge utilize inorganic nitrogen and phosphorous from the wastewaters for theor growth and cell division along with the production of molecular oxygen when they are cultivated in phototrophic mode. The filamentous nitrogen fixing cyanobacterium called *Aulosira fertilissima* can accumulate upto 85% (dry cell weight) of poly-β-hydroxybutyrate (PHB), a elastomeric, water insoluble, biocompatible, safe bioplastic with high degree of polymerization. (Samantaray, Nayak and Mallick 2011) have shown a high nutrient removal capacity of *A. fertilissima* with significant increase in dissolved oxygen (DO) content in a recirculatory aquaculture system while yielding valuable PHB. Cyanobacteria, especially the heterocystous forms, are well documented for their capability to act as potent biofertilizers. The production of high value compounds is more economical and sustainable in comparison to biofuels. Microalgae naturally produce lipids, proteins and carbohydrate based compounds that can be extracted through biorefinery approach (Ansari, et al. 2017).

ADVANCED WASTEWATER CONVERSION TECHNOLOGIES

Wastewater to meet domestic needs

The increasing water scarcity and drought conditions throughout the globe have resulted in the unavailability of clean drinking water to a large segment of the population. 785 million people fail to get basic drinking water service, including 144 million people relying on surface water. 1 in 3 people do not have access to safe drinking water globally.

Half of the population will be living in water-stressed area by 2025. Several water-stressed cities around the globe import the water, which requires pumping of the water from long distances to the place where it is most required at a high cost. In 2014, Los Angeles imported 8.9 billion litres of water/day to satisfy the need of its population, ranking it first in the world for cross-basin water transfer. The five cities that import most of the water from the outside source include Los Angeles, Boston, Mumbai, Karachi, and Hong Kong. Owing to the high cost of transfer of water and ecological harm, many countries are seeking an alternative to obtaining drinking water near the consumption point. Half of the fresh water in the cities is wasted, treated, and release back into the environment.

Toilet - to - tap approach to address potable water crisis

Reclamation of sewerage wastewater for drinking purposes by advanced techniques is known as potable water reuse. The indirect potable reuse (IPR) process reclaims the freshwater that is sent to the sewage treatment plant and is wasted. There is IPR in existence, a) Unplanned IPR (involves the release of the treated water into the natural environment – aquatic bodies, where it can be utilized by the cities downstream as a potential drinking water source), b) Planned IPR (involves the release of the water treated in the treatment plant at a very high degree into the developed groundwater system or aquatic body used as the source of drinking water). IPR has been the approach to reclaimed wastewater for several decades.

In contrast, direct potable reuse (DPR) has been adopted in the US, Australia, and South Africa. This approach involves further treatment of wastewater treated in the sewage treatment plant and is directly released into the drinking water distribution system, closer to where water is needed. There occurs no discharge of treated water into the natural environment like in IPR. A few of the advantages of DPR include the availability of drinking water close to the point of consumption and eliminates the cost associated with pumping the water from long distances. Likewise, it is an energy-efficient process.

Some of the cutting-edge technologies adopted by Singapore for recycled drinking water, which has been branded as NEWater, include efficient membrane filters with reactors that can harness energy from bacteria, incoporating nanotechnology for faster and cost effective treatment and downstream processing using reverse osmosis technique and ultra violet radiation (Tortajada and Nambiar, 2019). The Changi Water Reclamation plant of Singapore is one of the world's largest and most advanced reclamation facility which was commissioned in 2008 which produces treated effluents which further get ultracleaned into high-grade NEWater and it meet 30% of total water demand of the country. Other water reclamation technique involve the use of chemicals such as chlorine and cleaning agents like charcoal and sand and further elimination of biological hazardous agents is achieved via ozonation, membrane filters, UV and reverse osmosis.

In a process called reverse osmosis, tiniest particles are filtered out followed by ultraviolet light flashing to sterilise pathogenic microbes to supply in a pure state. The aquifers provide free storage, which would otherwise be expensive, and act as a psychological buffer to minimise the "yuck" factor. Even though the water is already drinkable, water gets naturally purified through the ground.

The treatment process for water reuse is basically 3 steps process that include

1. Microfiltration to eliminate solids, oils and bacteria

2. Reverse osmosis through a fine plastic membrane that removes viruses & pharmaceuticals toxins

3. Ultra Violet sterilization

CONCLUSIONS

The issue of water scarcity is persistent and has a planetary impact. The changing climatic conditions have aggravated the issue of water scarcity due to the higher frequency of floods, droughts and fluctuating precipitation patterns etc. Access to safe water access has come up as one of the most crucial, critical and global challenges of the 21st century. The decline in the availability of freshwater is attributed to the dwindling groundwater supplies, reduced river flows and lakes, higher pollution of water, increasing cost of water treatment and supply, irregular supplies and disputes over water. The freshwater forms the core of the daily necessities of not only humans but several florae, fauna, commercials setups, agriculture etc. Water plays a central role in maintaining the ecosystems on the surface of the earth. The measures to preserve freshwater should be on the priority list of each nation for safeguarding the population from chronic water scarcity very shortly.

Pure, unpolluted water is an essential resource to the environmental balance. Wastewater produced by city sewers, industrial processes, runoff from farms, urban areas, mining, forestry, oil wells, construction, etc causing water pollution has been a menace. This pollution causes concern for the health and wellbeing of all living organisms. Additionally, nutrient management is a critical challenge for the wastewater treatment industry as it causes eutrophication threatening our freshwater resources, with huge annual economic damages. Conventional nutrient removal treatment strategies are energy intensive, and largely focus on nutrient removal as opposed to recovery.

Microbial driven technologies of wastewater treatment are now being pursued in the interest of environmental concern and economic efficiency. The microalgal method competes well with traditional treatments on its ability to remove nutrients, coliform bacteria and heavy metals. These 'biofactories' are efficient nutrient absorbers that they can even detoxify mine wastewater. The byproduct of microalgal cultures, referred to as biomass, offer up a completely new opportunity for treatments plants in bioproducts which have numerous applications. Unfortunately, many wastewater treatment plants employing the microalgal method do not capitalize on microalgae harvesting.

The need of the hour is to develop and implement technologies and devise mitigation plans to preserve the freshwater resources on the surface of the earth. The fundamentals of each technique should be able to safeguard the available freshwater, minimize the wastage of water and recycle the used water. Several water conservation techniques are formulated to minimize water loss, as well as to preserve the available water resources. All the water conversation techniques aim to balance the demand and supply of water in an effective manner. The water conservation techniques vary with the sectors of water use such as irrigation, industrial and domestic uses.

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