International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 23s, 2025
https://theaspd.com/index.php

Catalytic Purification of Wastewater to Enable Sustainable Agricultural Crop Irrigation

Dr. Namrata Sinha[1]
[1]Department of Chemistry, Ranchi Women's College, Ranchi

Abstract: *The practice of using wastewater for agricultural irrigation is widely recognized and has been employed for decades, particularly in areas facing acute water shortages. With the growing pressures of population increase, industrial development, and climate change, the availability of freshwater resources is steadily diminishing. In this context, the recycling of treated wastewater has become a vital component of sustainable water management. This strategy not only helps to preserve limited freshwater supplies but also mitigates the environmental burden and pollution caused by discharging untreated wastewater into natural ecosystems.Reclaimed wastewater provides multiple scientific and practical advantages. Catalytic treatment technologies—such as photocatalysis, catalytic oxidation, and catalytic filtration—can enhance water quality by removing hazardous pollutants, microbial pathogens, and toxic substances, while retaining valuable nutrients that support healthy plant development. When subjected to these treatments, wastewater becomes a safe and cost-effective option for agricultural irrigation, promoting both resource efficiency and environmental sustainability.A significant benefit of recycled wastewater lies in its elevated concentrations of nutrients and organic matter, often surpassing those found in many commercial fertilizers. It generally contains key plant macronutrients, including nitrogen (N), phosphorus (P), sulfur (S), and carbon (C), as well as essential micronutrients. These components play a critical role in boosting crop yields, improving soil health, and reducing dependency on synthetic fertilizers. Consequently, farmers can lower production costs and decrease the ecological footprint associated with fertilizer manufacturing and usage. Nevertheless, the nutrient-rich nature of such water requires careful management. Excessive levels of certain minerals can disrupt plant nutrition, stimulate uncontrolled vegetative growth, or even harm crops. For this reason, precise knowledge of the treated water's nutrient profile and appropriate application methods, tailored to crop requirements and growth stages, are essential.This review synthesizes current research on catalytically treated wastewater as an irrigation resource, emphasizing its advantages, limitations, and potential contributions to sustainable farming systems.*

Keywords: *Catalyst, Waste Water, Treated, Untreated, Water Pollution, Agricultural Irrigation, Water Treatment, Sewage, Efficient Use of Water, Minerals, Fresh Water*

I. INTRODUCTION

The use of catalyst-treated wastewater for irrigation has emerged as an efficient and sustainable approach to managing and regulating water resources, particularly in regions facing seasonal or chronic water scarcity. This method addresses water shortages caused by irregular rainfall patterns, prolonged dry seasons, or uneven distribution of water availability throughout the hydrological year. While the practice of using wastewater for irrigation dates back centuries, historical applications were often informal, lacked quality control, and did not meet established health or safety standards. Over time, as human knowledge and technological capacity have advanced, the treatment and management of wastewater have evolved considerably, now enabling compliance with environmental and agricultural quality benchmarks. The adoption of catalytic treatment technologies has further enhanced the safety and effectiveness of wastewater for agricultural purposes.

In recent years, wastewater reuse for irrigation has gained significant momentum globally. Countries such as India, China, and numerous others—especially in the developing world—have increasingly recognized its role in supporting agricultural production and water security. In these regions, wastewater irrigation has become particularly important due to rapid population growth, industrial expansion, and the corresponding strain on freshwater resources. Despite its growing use and potential economic benefits, awareness of its strategic importance remains limited among marginalized farming communities. Many farmers may not fully understand the long-term advantages of treated wastewater, even though it has been applied in agriculture for decades. At the same time, there are health risks associated with the use of inadequately treated or untreated wastewater, especially for workers in direct contact with the water and for the surrounding public..

The market potential for wastewater irrigation is considerable, driven by the absence of alternative water sources in many areas. This scarcity has created a viable and expanding market for treated wastewater as an irrigation resource. However, its adoption in developing countries is not without challenges. Technical

knowledge of advanced treatment methods—such as catalytic oxidation, photocatalysis, and membrane-coupled catalytic processes—is often limited, leading to concerns about reliability and consistency in water quality. Furthermore, urbanization has intensified competition for freshwater supplies, reducing the availability of clean water for agricultural use. As a result, many urban and peri-urban farmers resort to using treated or partially treated wastewater sourced directly from municipal sewage systems or other polluted water bodies.
Hence the agricultural irrigation use of untreated or polluted waste water has been associated to land application and production of crops for a country. Likely so, in India waste water irrigation is used extensively for crops such as vegetables, fruits, cereals, flowers and also fodders. By using domestic waste water both foo and cash crop are irrigated.

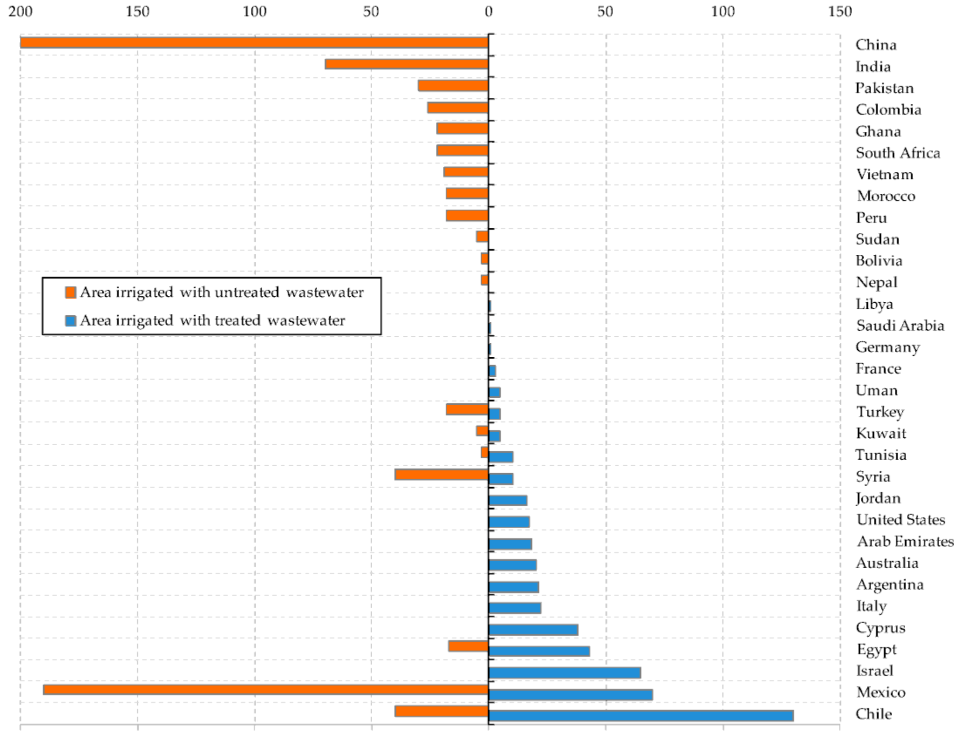


Image: Area irrigated with treated and untreated wastewater.

II. USE OF WASTEWATER IN IRRIGATION SYSTEM

The use of untreated waste water agricultural activities are mostly not common in and around urban areas. It can be witnessed in rural areas though, in communities located near streams where mostly waters discharge. Unless the streams are self-purifying the farmers use the polluted waters only. According to a survey it was found that four out of five cities use untreated water for agricultural irrigation. Waste water needs to be used so that the health of crop and public both are maintained. Treated waste water is economical as the by-products will be better than what untreated would produce. Recycled waste water has more nutrients and organic matter than any commercially sold fertilizer in the market. This is possible as all major minerals like N, P, S and C are present and along with some micro nutrients they help in increasing the growth.

III. BENEFITS OF AGRICULTURAL REUSE

Using catalyst treated waste water is good for agricultural crops, human health and also for the economy. Due to the declining ground water level caused due to growing population, climate changes and seasonal backlashes, using treated waste water is an alternate practice that has been adopted in all regions and especially those with shortage of water.
One of the major accepted and acknowledged benefit of using treated waste water is that it decreases the pressure on fresh water resources. Thus, slowing the rate of water level decline. If used in agriculture we can save up to 70% of water was being wasted as agriculture is the greatest user of water resources.
Now that water is being treated before discharge, this will ensure that the pollution in water bodies is reduced thereby improving the quality of water at the source resource of water bodies. Ultimately the quality and quantity of ground/surface water is increases. Talking commercially and economically, setting

up of plants will generate work for more people as installations will be needed for optimization of treatment so that an effective result is procured. In challenging regions (climatic and geographically), low cost treatment system can be feasible option as there are so many technologies coming as options to fulfil the requirement.

IV. EXPERIMENT AND RESULTS

Sewage water, or untreated wastewater, is often heavily contaminated as it carries a wide range of solid wastes. These include human and animal excreta, domestic refuse, bodily discharges, household garbage, and even non-biodegradable materials that fail to decompose easily. As a result, untreated wastewater typically has a much higher hardness level and ionic concentration compared to regular groundwater. This difference in composition significantly influences its agricultural potential. While groundwater is generally considered cleaner, it lacks the diverse array of nutrients and minerals that sewage water inherently contains.One of the major characteristics of untreated wastewater is the presence of nutrient-rich effluents, particularly essential elements such as nitrogen (N), phosphorus (P), and sulfur (S). These nutrients are fundamental to plant growth and development, serving as natural fertilizers that enrich the soil and promote healthy crop performance. Nitrogen is crucial for leaf development and chlorophyll synthesis, phosphorus supports root and shoot growth, and sulfur aids in protein formation and overall plant vigor. Beyond macronutrients, untreated wastewater often contains micronutrients that groundwater fails to supply in sufficient quantities, further contributing to plant health.Empirical studies and controlled experiments have shown that irrigation with sewage water leads to marked improvements in several agronomic parameters. When compared with crops irrigated using only groundwater, plants receiving sewage water demonstrated superior shoot length, increased biomass in both fresh and dry weight, and enhanced leaf quality and quantity. These improvements can be attributed directly to the nutrient density of wastewater, which compensates for deficiencies commonly found in nutrient-poor soils and limited groundwater supplies. In essence, wastewater functions as both an irrigation source and a natural fertilizer, offering a dual advantage to farmers. It is therefore reasonable to argue that properly treated wastewater could perform equally well, if not better, than untreated sewage water for agricultural purposes. While untreated wastewater carries the risk of pathogens, toxic substances, and environmental contamination, treated wastewater retains much of the beneficial nutrient content while eliminating or reducing harmful components. This makes treated wastewater a safer and more sustainable option for long-term agricultural use. It combines the productivity-enhancing qualities of sewage water with the health and environmental safeguards necessary for sustainable farm. Adopting treated wastewater for irrigation has additional benefits beyond crop performance. By reducing dependency on chemical fertilizers, it lowers agricultural input costs while simultaneously decreasing the negative environmental effects of excessive fertilizer application, such as eutrophication and soil degradation. It also alleviates pressure on freshwater resources, which are already under stress from overuse and climate variability.In conclusion, while untreated sewage water has demonstrated its capacity to boost crop yield and quality due to its high nutrient content, treated wastewater offers a more balanced and sustainable approach. It provides similar, if not superior, agricultural benefits while addressing concerns of safety, hygiene, and long-term environmental sustainability. Thus, integrating treated wastewater into irrigation practices can play a vital role in improving agricultural productivity and securing food resources for the future.

V. COMPARISON OF PHYSICO-CHEMICAL CHARACTERISTICS OF SEWAGE WASTEWATER AND GROUND WATER

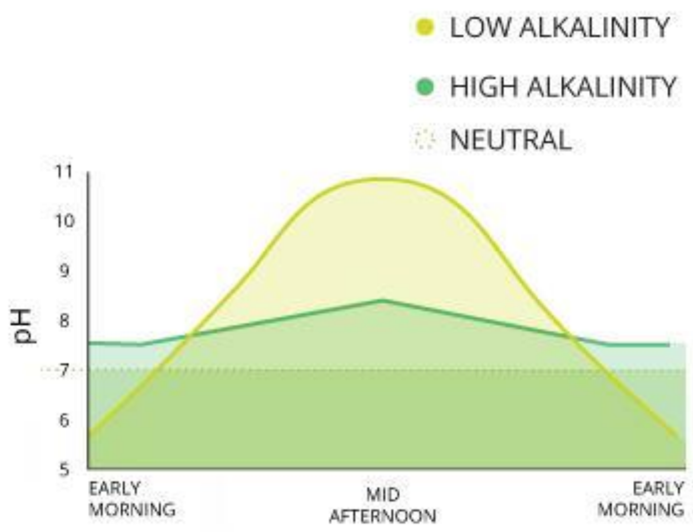
Determination	Sewage wastewater	Ground water
Ph	8.2	7.5
EC	1210dSm^{-1}	573dSm^{-1}
TDS	1421 mg/l	542mg/l
BOD	155.18 ,,	16.75,,
COD	366.0,,	38.5,,
Calcium	157.5m.mol/l	23.98 m.mol/l
Magnesium	132.0 ,,	26.0 ,,
Carbonate	94.85 ,,	19.32 ,,
Bicarbonate	219.2 mg/l	68.0 mg/l

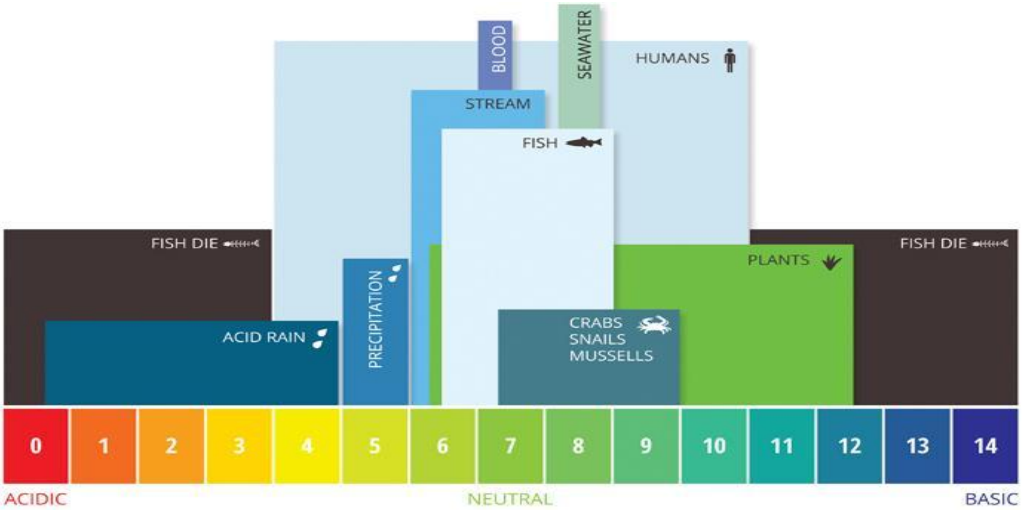
Chloride	130.70 mg/g	74.66 mg/l

As it can be seen sewage water has more mineral content than ground water, it resulted in usage of waste water which has improved the parametrical results such as chlorophyll content and rate of photosynthesis as compared to ground water. Application of waste water decreases the requirement of fertilizers and reduces pressure on fresh water bodies.

VI. THE CHARACTERISTICS AND COMPOSITION OF LIQUID DISTILLERY EFFUENT PARAMETERS:

COLOUR	Dark Brown
ODOUR	Unpleasant
PH	7.8
ELECTRICAL CONDUCTIVITY	2.8dSm[1]
ORGANIC CARBON	.8 %
TDS	14635 mg/l
BOD	462 MG/L
TSP(Total suspended particle)	38 mg/l
COD	20000 mg/l
NITROGEN	.19 %
TOTAL Phosphorus	6 ppm
TOTAL Potassium	53356ppm
TOTAL Sulphite	4.2 m.mol/l
TOTAL Calcium	100 ,,
Total Magnesium	12 ,,
Chloride	14.4 ,,
Sodium	20.00 ppm
Zinc	6.00 ,,
Copper	3.00 ,,
Iron	38.0,,
Manganese	2.00,,
Boron	0.4 ,,
Carbonates	Nil
Bi Carbonate	150 /l





VII. EFFECT OF WASTEWATER ON PLANT GROWTH

Agriculture remains one of the largest consumers of wastewater, and this is unsurprising given the ever-increasing global demand for food. With the pressure of feeding a rapidly growing population, farmers and agricultural systems are constantly in search of reliable and cost-effective water sources. Wastewater, when properly treated, provides a sustainable alternative, not only addressing water scarcity but also enriching crops with essential nutrients. Unlike conventional groundwater, which is often limited in its nutrient profile, treated wastewater typically contains higher levels of nitrogen, phosphorus, potassium, and other vital minerals. These nutrients act as natural fertilizers, enabling plants to grow stronger, healthier, and more resilient.

The use of wastewater in irrigation has also been linked to higher crop yields. Because it provides both water and nutrients simultaneously, it enhances plant growth efficiency and improves soil fertility over time. This dual benefit is particularly valuable in regions where both water scarcity and soil nutrient depletion are major agricultural challenges. Furthermore, by supplying nutrients directly through irrigation, wastewater reduces the dependency on synthetic or commercial fertilizers. This not only lowers production costs for farmers but also reduces the environmental burden associated with the excessive use of chemical fertilizers, such as soil degradation and water pollution.

From an economic perspective, wastewater irrigation represents a cost-effective practice. By decreasing the need for purchased fertilizers and improving crop yields, it supports more sustainable farming systems and contributes to food security. For consumers, the benefits extend further, as wastewater-fed crops can be more nutrient-rich and potentially healthier when managed under safe treatment and application standards.In summary, wastewater use in agriculture offers a win-win situation: it addresses water scarcity, enhances soil fertility, reduces input costs, and supports higher agricultural productivity, making it a critical strategy for sustainable food production in the future.

VIII. LIMITATIONS ASSOCIATED WITH AGRICULTURAL WASTE WTER REUSE

Although treated wastewater is increasingly promoted as a valuable resource for addressing agricultural water demands, it is not without potential drawbacks. Much like any other resource, it carries certain disadvantages that may affect the environment, particularly soil and land quality. Long-term use of treated or catalytic wastewater for irrigation has been reported to alter both the physical and chemical parameters of soil. Over extended periods, such changes can influence soil structure, texture, and nutrient composition, thereby affecting its overall capacity to support healthy crop growth.Recent studies also reveal that wastewater irrigation may disrupt the biological balance of soils. In particular, significant variations have been observed in the structural characteristics and abundance of microbial biomass. Soil microorganisms form the backbone of soil fertility as they regulate nutrient cycling, decompose organic matter, and maintain ecological stability. However, shifts in microbial populations whether in terms of diversity or activity can disturb these natural processes, leading to reduced soil

productivity and long-term degradation.The alteration of soil chemistry, such as changes in pH, increased salinity, and the buildup of heavy metals, further complicates the problem. These chemical imbalances, coupled with microbial disturbances, may cause a gradual decline in soil fertility. One of the most critical consequences of this decline is the reduction in soil organic matter. Organic matter plays a crucial role in enhancing soil structure, water retention, and overall stability. When its content decreases, the soil

becomes less capable of holding water, more prone to compaction, and increasingly vulnerable to erosion and degradation.
Therefore, while the reuse of treated wastewater in agriculture provides significant benefits in terms of water availability and nutrient recycling, its application must be carefully managed. Regular monitoring of soil health, along with the adoption of sustainable irrigation practices, is essential to maximize benefits while minimizing adverse impacts on soil quality and agricultural productivity.

DISCUSSION

The reuse of treated wastewater, particularly through catalytic purification, presents itself as a significant solution for sustainable agricultural irrigation. The findings of this review highlight both the advantages and the limitations of wastewater reuse, reflecting the dual nature of this practice. On one hand, treated wastewater provides essential nutrients, reduces pressure on freshwater resources, and supports soil fertility, while on the other hand, its long-term effects on soil quality and microbial ecosystems cannot be overlooked.

One of the most prominent benefits of wastewater reuse lies in its nutrient-rich composition. Unlike conventional groundwater, which is often deficient in essential elements, treated wastewater typically contains nitrogen, phosphorus, potassium, sulfur, and various micronutrients. These nutrients act as natural fertilizers, reducing the dependence on synthetic chemical fertilizers. Consequently, farmers not only cut down input costs but also contribute to reducing the environmental footprint associated with fertilizer production and overuse. The dual role of wastewater as both an irrigation source and a nutrient provider offers a unique advantage in agricultural systems, especially in regions facing both water scarcity and declining soil fertility.

Empirical evidence suggests that crops irrigated with wastewater often exhibit higher shoot length, greater biomass, and improved leaf quality compared to those irrigated with groundwater. This reinforces the argument that wastewater, when treated properly, can enhance productivity while simultaneously conserving freshwater resources. The adoption of catalytic purification technologies, such as photocatalysis, catalytic oxidation, and filtration, ensures that harmful pathogens and toxic contaminants are eliminated, making wastewater safe for agricultural use while retaining its beneficial nutrient profile.

However, despite these benefits, challenges remain. Long-term irrigation with wastewater, whether treated or untreated, has been associated with significant changes in soil chemistry and biology. Shifts in soil pH, accumulation of salts, and the presence of heavy metals may pose risks to soil health over time. More importantly, studies indicate that wastewater irrigation can disturb microbial biomass, which is crucial for nutrient cycling and organic matter decomposition. Since microorganisms play a key role in maintaining soil fertility and stability, disruptions in microbial communities could compromise long-term soil productivity.

Another critical concern is the reduction of organic matter in soils irrigated with wastewater. Organic matter not only improves soil structure but also enhances its capacity to retain water. A decline in organic content may therefore increase soil vulnerability to erosion, compaction, and decreased water-holding capacity, ultimately threatening agricultural sustainability. These issues highlight the importance of careful management and continuous monitoring when adopting wastewater reuse.

Economically, wastewater reuse has strong potential. It reduces the burden on groundwater extraction, decreases fertilizer costs, and creates opportunities for employment through the establishment and maintenance of treatment facilities. Furthermore, the practice can significantly reduce pollution loads in rivers and lakes, thereby improving the quality of aquatic ecosystems. From a policy standpoint, the integration of wastewater reuse into agricultural frameworks is both timely and necessary, especially in water-stressed regions.

In summary, catalytic wastewater reuse embodies a promising pathway toward sustainable agriculture. Its nutrient-rich profile, cost-effectiveness, and contribution to water conservation are undeniable. Nevertheless, the associated risks—particularly those affecting soil health—must be mitigated through site-specific application, rigorous monitoring, and regulatory frameworks. Only then can treated wastewater irrigation fulfill its potential as a sustainable, safe, and productive agricultural practice.

IX. CONCLUSION

The problem of water scarcity is no longer a hidden concern but a global reality that continues to worsen with time. Increasing population, urban expansion, and climate change are all contributing to the depletion of freshwater resources. Among various sectors, agriculture and irrigation stand out as the largest consumers of water, accounting for the majority of withdrawals worldwide. This makes the sector highly vulnerable to water shortages and in urgent need of alternative solutions that can ensure a steady supply of water for food production.

One effective approach is the reuse of treated or catalytic wastewater. Many regions across the globe already face severe freshwater shortages, making water recycling a practical and necessary solution. Catalytic wastewater, in particular, has shown promising benefits for agriculture. Unlike conventional groundwater, which is often overexploited and limited in nutrient content, treated wastewater can enhance soil fertility and crop productivity. This is because such water often contains essential nutrients, including nitrogen, phosphorus, and potassium, which act as natural fertilizers. As a result, farmers can reduce their reliance on synthetic fertilizers, lowering production costs and minimizing the environmental impact of excessive chemical use.

Furthermore, reusing treated wastewater significantly reduces pressure on freshwater bodies such as rivers, lakes, and underground aquifers, helping to preserve these ecosystems and maintain ecological balance. By decreasing the demand for chemical fertilizers and reducing untreated effluent discharge, wastewater reuse also contributes to sustainable agricultural practices and cleaner environments.

For these reasons, it is crucial that strategies for wastewater reuse are developed and implemented at the local level. Policies must be designed to suit regional conditions, including water availability, soil type, and crop requirements. Making wastewater recycling a mandated practice in agriculture can pave the way toward long-term water security, sustainable farming, and a healthier environment for future generations.

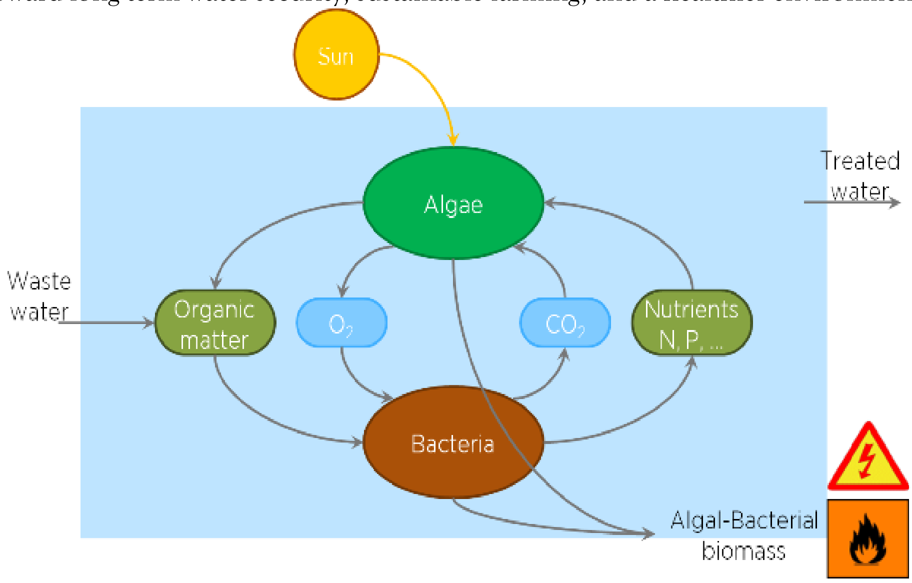


Image: waste water to treated water

REFERENCES

[1] María Fernanda Jaramillo ID and Inés Restrepo, Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits, Published: 11 October 2017 MDPI

[2] Editor-in-Chief Prof. S. S. Katiyar, EVERYMAN'S SCIENCE, Vol. XLVII No. 2 (June '12 – July '12)

[3] Blanca Jiménez, Pay Drechsel, Doulaye Koné, Akiça Bahri, Liqa Raschid-Sally and Manzoor Qadir, Wastewater, Sludge and Excreta Use in Developing Countries: An Overview

[4] ClaudeDescorme. Catalytic wastewater treatment: Oxidation and reduction processes. Recent studies on chlorophenols

[5] Isabel Castelo-Branco,Adrían Silva,Rosa. M. Quinta-Ferreira, Catalysts for Wastewater Treatment, (NAII, volume 69)

[6] Derrouiche S[1], Bourdin D, Roche P, Houssais B, Machinal C, Coste M, Restivo J, Orfão JJ, Pereira MF, Marco Y, Garcia-Bordeje E., Process design for wastewater treatment: catalytic ozonation of organic pollutants. Water Sci Water Sci Technol. 2013;68(6):1377-83 . doi: 10.2166/wst.2013.384