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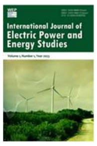

Design and Evaluation of Solar Photocatalytic Reclamation for Purification of Agricultural Wastewater

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ABSTRACT

The study designed and assessed a solar-powered wastewater treatment system tailored for purifying agricultural wastewater in urban residential areas. Integrating advanced technologies, primarily solar energy-driven, the system aims to effectively remove pollutants to meet discharge standards. The detailed analysis included wastewater composition, sources and suitable treatment processes, with emphasis on comparative feasibility analysis and recommended quality assurance measures. The results of the study indicate that solar photocatalytic technology has great potential for degrading pollutants and reducing operating costs. The economic analysis showed that the technology is financially viable with a payback period of about 4.64 years. The photocatalytic system offers a higher level of efficiency and flexibility compared to existing methods. Emphasis is placed on implementing quality assurance to meet safety and environmental standards.

KEYWORDS

Solar Photocatalytis; Purification; Agricultural Wastewater.

1. INTRODUCTION

1.1. Background of Wastewater from Agricultural Productions

Agricultural activities are the backbone for meeting global demand for food, textile materials and energy. However, agricultural activities also produce a large number of by-products, namely agricultural wastewater, which is a complex mixture of pollutants that, if left untreated, can cause serious environmental problems. Agricultural wastewater is a mixture of various pollutants generated by irrigation methods, animal husbandry and crop cultivation methods. These pollutants are diverse and include organic matter, nutrients such as nitrogen and phosphorus, pesticides, pathogens, heavy metals and sediments [1].

The discharge of untreated or inadequately treated agricultural wastewater can have serious consequences, casting a shadow of environmental degradation over soils, surface water bodies and groundwater reservoirs. Its effects ripple through ecosystem dynamics and pose a serious threat to biodiversity and human well-being. These risks are exacerbated by pollutants entering the food chain through irrigation canals or runoff pipes and potentially contaminating important drinking water sources [1]. In addition, the threat is exacerbated by the excess of nutrients, especially nitrogen and phosphorus, leading to eutrophication of water bodies. This phenomenon leads to harmful algal blooms that catalyze oxygen depletion and destabilize aquatic habitats and fisheries. In essence, the management and purification of agricultural wastewater is an overarching issue that requires a multifaceted strategy to mitigate its adverse effects on environmental integrity and human health.

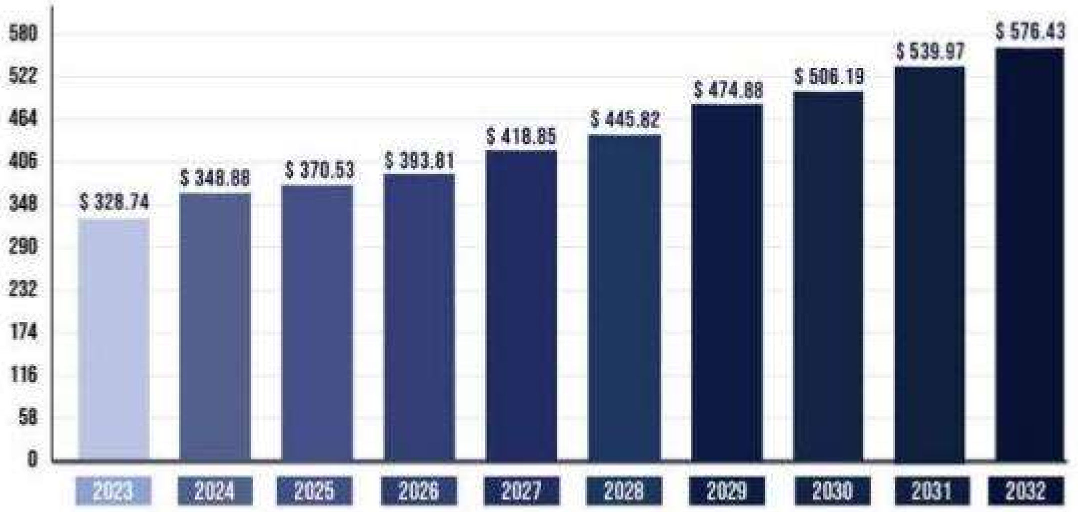


Figure 1. Global Agricultural Wastewater Treatment Market Size (Billion $) [2]

1.2. Application of Solar Energy in Wastewater Treatment

As an abundant renewable resource, solar energy has gained attention in recent years for its potential applications in various fields, including wastewater treatment. Escalating global concerns over water scarcity, environmental pollution and energy sustainability have prompted the exploration of innovative and sustainable technologies to address these challenges. In this context, the use of solar energy to transform conventional wastewater treatment processes into more energy-efficient and environmentally friendly alternatives is promising.

Solar energy can be utilized through various mechanisms, such as photovoltaic panels for electricity generation and solar collectors for heat production. In wastewater treatment, solar energy is particularly advantageous due to its inherent compatibility with photocatalytic and photovoltaic processes [3]. Photocatalysis is driven by semiconductor photocatalysts such as titanium dioxide (TiO2) or zinc oxide (ZnO),

which use solar irradiation to trigger chemical reactions that degrade organic pollutants and pathogens in wastewater [4]. Similarly, photovoltaic systems can power a range of treatment processes, including aeration [5], membrane filtration, and disinfection, thereby reducing reliance on grid power and minimizing operating costs.

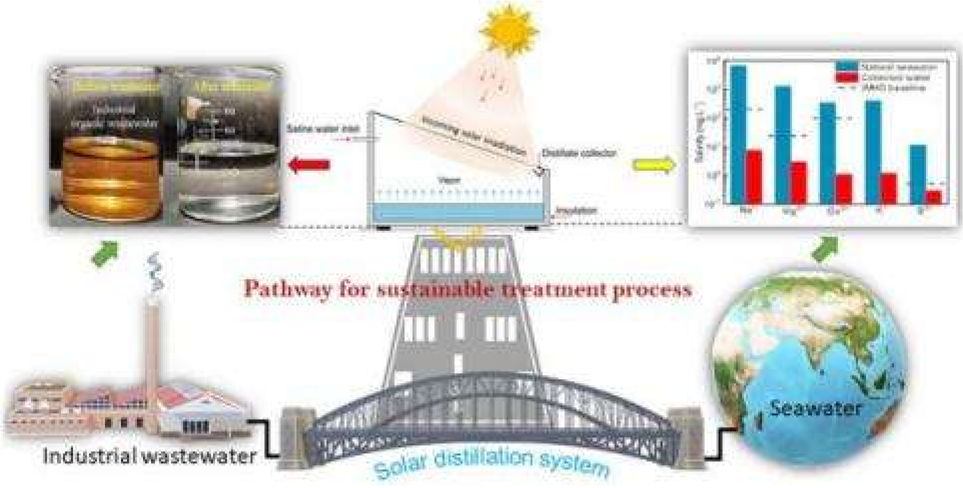


Figure 2. Concept of the solar energy-driven wastewater and seawater distillation[3]

The application of solar energy in wastewater treatment has several significant benefits. First, it provides a sustainable renewable energy source [3], thus reducing greenhouse gas emissions and mitigating the environmental impacts associated with conventional energy sources. In addition, solar-powered treatment systems can be decentralized to enable wastewater treatment at the site or community level [5], especially in remote or off-grid areas where centralized infrastructure is limited [5]. In addition, solar-powered processes can improve treatment efficiency and reliability as they are less susceptible to fluctuations in grid power supply and operational interruptions.

1.3. Overview of Photocatalytic Processes in Wastewater Treatment Domain

The implementation of photocatalytic reactions in wastewater treatment offers a promising avenue for achieving sustainable and efficient purification processes. Photocatalysis utilizes the energy of photons to initiate a chemical reaction and typically employs semiconductor materials as catalysts [3]. In recent years, this approach has gained attention for its potential to address key challenges in wastewater transformation.

The photocatalytic process offers unique advantages for wastewater treatment based on the advantages of solar energy as previously described. By utilizing solar irradiation, photocatalysis promotes catalyst activation, thereby accelerating the degradation of organic pollutants and converting harmful pollutants into benign by-products.

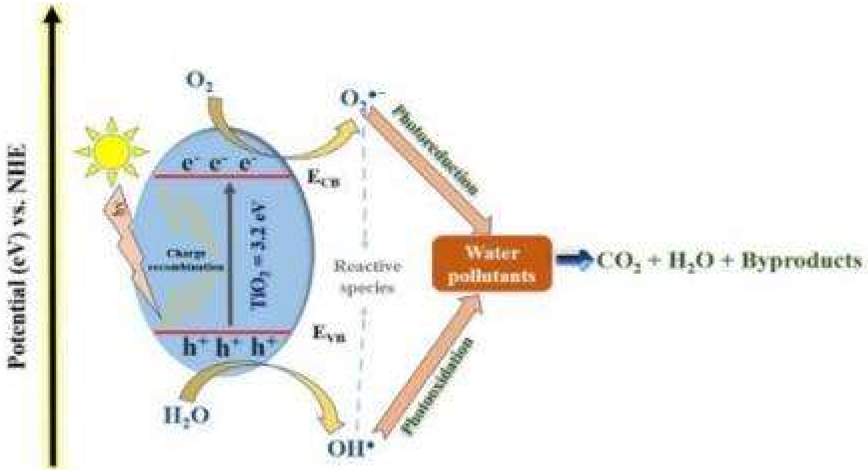


Figure 3. Mechanism of the photocatalytic action of a TiO2 sample in wastewater treatment[3]

In wastewater treatment, photocatalytic reactions play a crucial role in breaking down various pollutants found in water. When semiconductor photocatalysts like titanium dioxide (TiO2) or zinc oxide (ZnO) are exposed to sunlight or artificial light, they become energized, creating electron-hole pairs. These charged particles then interact with substances on the catalyst's surface, leading to the breakdown of organic pollutants and the oxidation of inorganic contaminants.

Organic pollutants like dyes, pharmaceuticals, and volatile organic compounds (VOCs) are particularly prone to degradation through photocatalytic processes [6,7]. As a result of photocatalytic oxidation, these pollutants break down into safer compounds like carbon dioxide and water. Likewise, inorganic contaminants such as heavy metals and pathogen can also be altered or immobilized on the surface of the photocatalyst, reducing their ability to harm the environment [7].

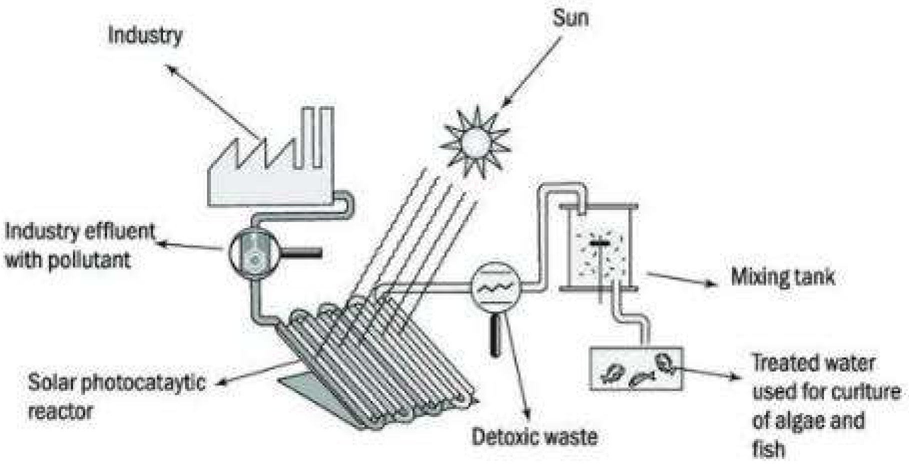


Figure 4. Schematic diagram of a photocatalysis-based wastewater treatment system [7]

The transformation of pollutants in wastewater through photocatalytic reactions is a sustainable and environmentally sound method of water purification. By utilizing solar energy, photocatalytic technology provides a pathway for the effective removal and degradation of pollutants, ultimately producing cleaner water that can be reused or discharged into the environment.

2. PROBLEM STATEMENT AND RESEARCH AIMS

2.1. Problem Statement

The agricultural sector generates a significant volume of wastewater containing various pollutants, posing environmental challenges and necessitating effective treatment methods. Traditional wastewater treatment techniques may prove insufficient in addressing the diverse composition and scale of agricultural wastewater pollution. In this context, the application of photocatalytic processes in agricultural wastewater treatment presents a promising avenue. However, there remains a need for comprehensive research to evaluate the feasibility, efficiency, and practical implementation of photocatalysis in treating agricultural wastewater.

2.2. Research Aim:

The aim of this study is to investigate the efficacy and feasibility of employing photocatalytic processes for the treatment of agricultural wastewater, focusing on insert specific type of agricultural wastewater. This research aims to:

(1) Analyze the components of the chosen agricultural wastewater, identifying their origins, pathways, and pollutants using suitable measurement tools.

(2) Devise a suitable treatment method tailored to the selected agricultural water/wastewater, explaining the reasoning behind the choice and comparing its pros and cons.

(3) Assess the practicality of the proposed treatment method, considering factors like space, finances, and potential implementation sites.

(4) Ensure that the treated wastewater adheres to quality standards for release into natural water bodies by confirming pollutant levels within acceptable limits and specifying necessary equipment for measurement and oversight.

Through these research objectives, this study attempts to provide valuable insights into the application of photocatalytic processes for the treatment of agricultural wastewater, with the ultimate goal of mitigating environmental pollution and promoting sustainable agricultural practices.

3. METHODOLOGY AND PROGRAM DESIGN

3.1. Scenario Selection of Wastewater Treatment

Situated in the picturesque Hahndorf region of South Australia, Beerenberg Farms is an outstanding example of sustainable farming practices, with over 183 years of experience in growing quality fruit and vegetables. The family-owned business has an unwavering commitment to environmental stewardship and has earned a reputation for its careful farming methods and high quality food production [8].

Figure 5. The location of Beerenberg Farm on Google Maps

The Berenberg Farm covers a vast area and grows a variety of fruits such as strawberries, raspberries, tomatoes and other seasonal produce [9]. Through a harmonious combination of tradition and innovation, the farm not only maintains the vitality of the land, but also strives to provide fresh, nutritious produce to discerning consumers both locally and internationally.

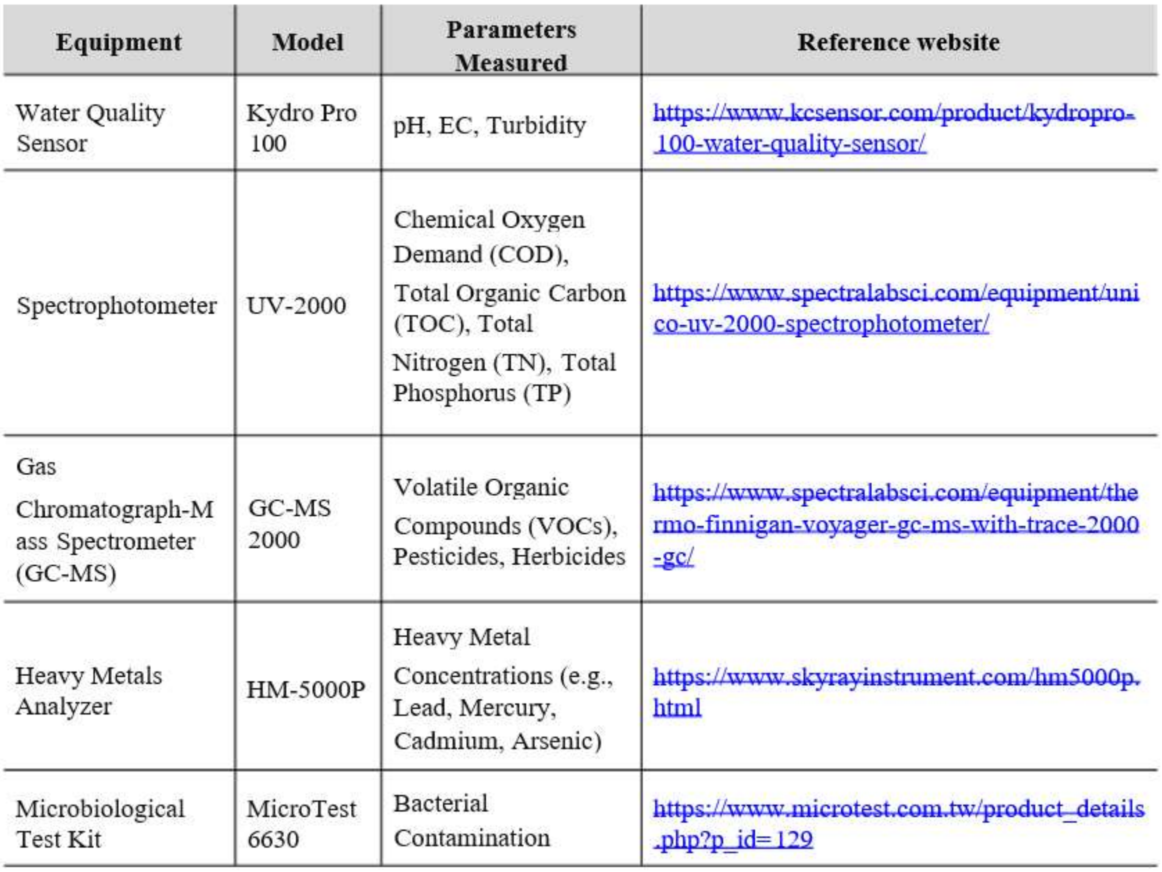
Figure 6. Agricultural and secondary by-products from Beerenberg Farm [10]

However, like many of its counterparts in the agricultural sector, Berenberg Farms has faced multiple challenges in wastewater management along with accolades and achievements [9]. In response to the urgent need for wastewater management, Berenberg Farms is ready to embark on a transformational journey towards sustainable solutions. This report aims to utilize the innovative potential of photocatalytic technology to implement a tailor-made agricultural wastewater treatment system at the farm.

3.2. Agricultural Wastewater Detection and Quantification

To comprehensively analyze the composition of wastewater from Beerenberg Farm, we will conduct a thorough examination of the farm's agricultural processes as outlined on the Beerenberg Farm website [9, 10]. This investigation aims to identify the main crops grown, cultivation techniques employed, and potential sources of contaminants in the wastewater. Sampling surveys and consultations will be our primary methods for gathering data [9]. We'll collect water samples from various locations across the farm, including irrigation systems, drainage channels, and processing facilities. Moreover, insights from discussions with farm managers and workers will enhance our understanding of agricultural practices and contamination sources [10]. To measure different parameters accurately, we'll utilize specialized detection equipment. Water quality sensors will assess pH, electrical conductivity (EC), and turbidity [11], while spectrophotometers will analyze Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Total Nitrogen (TN), and Total Phosphorus (TP) [12]. Additionally, gas chromatograph-mass spectrometers (GC-MS) will identify volatile organic compounds (VOCs), pesticides, and herbicides, and heavy metals analyzers will detect concentrations of lead, mercury, cadmium, and arsenic [12]. Microbiological test kits will evaluate bacterial contamination levels [12].

Table 1. Testing equipment scheme



Equipment	Model	Parameters Measured	Reference website
Water Quality Sensor	Kydro Pro 100	pH, EC, Turbidity	https://www.kcsensor.com/product/kydropro-100-water-quality-sensor/
Spectrophotometer	UV-2000	Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Total Nitrogen (TN), Total Phosphorus (TP)	https://www.spectralabsci.com/equipment/unico-uv-2000-spectrophotometer/
Gas Chromatograph-Mass Spectrometer (GC-MS)	GC-MS 2000	Volatile Organic Compounds (VOCs), Pesticides, Herbicides	https://www.spectralabsci.com/equipment/thermo-finnigan-voyager-gc-ms-with-trace-2000-gc/
Heavy Metals Analyzer	HM-5000P	Heavy Metal Concentrations (e.g., Lead, Mercury, Cadmium, Arsenic)	https://www.skyrayinstrument.com/hm5000p.html
Microbiological Test Kit	MicroTest 6630	Bacterial Contamination	https://www.microtest.com.tw/product_details.php?p_id=129

Figure 7. Detector scheme for quantitative analysis of sewage (schematic diagram)

The final results of these efforts will be summarized in a comprehensive report detailing the average concentrations and ranges of various pollutants in the Berenberg Farms wastewater. Because the study has not yet been fully developed, this report provides only the table design options.

Table 2. Water quality survey results summary table design scheme

Parameter	**Average Concentration (mg/L)**	**Range of Concentration (mg/L)**	**Sources of Contamination**
pH	X	X	Agricultural Chemicals,
			Organic Matter
EC	X mS/cm	X - X mS/cm	Fertilizers, Soil Leaching
Turbidity	X NTU	X - X NTU	Sediments, Suspended Solids
COD	X mg/L	X - X mg/L	Organic Matter, Pesticides
TOC	X mg/L	X - X mg/L	Organic Matter, Fertilizers
TN	X mg/L	X - X mg/L	Fertilizers, Animal Waste
TP	X mg/L	X - X mg/L	Fertilizers, Soil Erosion
VOCs	X g/L	X - X g/L	Pesticides, Herbicides
Heavy Metals	X mg/L	X - X mg/L	Fertilizers, Soil Contamination
Bacterial Contamination	X CFU/mL	X - X CFU/mL	Animal Waste, Soil Contact

3.3. Scheme Design of Agricultural Wastewater Purification by Photocatalysis

3.3.1. Research Status and Industrial Experience of Wastewater Purification by Photocatalysis

Before the scheme design, this paper firstly investigates and summarizes the technical status and industry experience.

Numerous studies have explored the use of photocatalysis for purifying wastewater in different industries. These studies aim to understand how photocatalytic reactions work, improve the materials used as catalysts, and make the process more efficient. Researchers have investigated the kinetics and thermodynamics of photocatalytic degradation, which helps to understand how these reactions happen and what factors affect their effectiveness. Advances in nanotechnology have led to the development of new photocatalysts that work better and last longer. Materials like titanium dioxide (TiO2), zinc oxide (ZnO), and other metal oxides have been studied extensively for their potential in treating wastewater. Researchers have also used techniques like doping and adding co-catalysts to change the properties of photocatalysts, making them perform better under different conditions.

Table 3. List of catalysts used for degradation of pollutants [13]

Catalyst	**Authors**	**Target Pollutants**	**Degradation Efficiency (%)**
DG@Fe3O4	Wang et al. (2019)	Methylene blue	99
Composite catalyst of Fe3O4	Zhang et al. (2015), S. Sun et al. (2019)	Methylene blue	96.88
Fe-C/PTFE	Y. Sun et al. (2019)	2,4-DCP	95
Fe-C/TiO2	Zhang et al. (2020)	Aflatoxin B1	95
CuO/SiO2	Ghasemi et al. (2019)	Rhodamine B (RhB)	99
CuVOx	Elhalil et al. (2018)	Fluconazole	91.3
Cu-Fe-NLDH	Lu et al. (2019)	Gentamicin	98.9
Mg-ZnO.Al2O3	T. Zhang et al. (2019)	Caffeine	95
TiO2/biochar	Y. Zhang et al. (2019)	Methyl orange	96.88
Fe2O3/ATP	Zhang et al. (2015)	Methylene blue	95
Fe3O4@β-CD/MWCNT	Zhang et al. (2020)	Tetrabromobisphenol A	97

Moreover, studies have examined how photocatalytic processes can be combined with various treatment methods like adsorption, membrane filtration, and advanced oxidation processes (AOPs) [13, 16]. Researchers have investigated the synergistic effects when photocatalysis is integrated with these complementary techniques, aiming to enhance pollutant removal efficiencies and overcome the limitations associated with each method [13, 17].

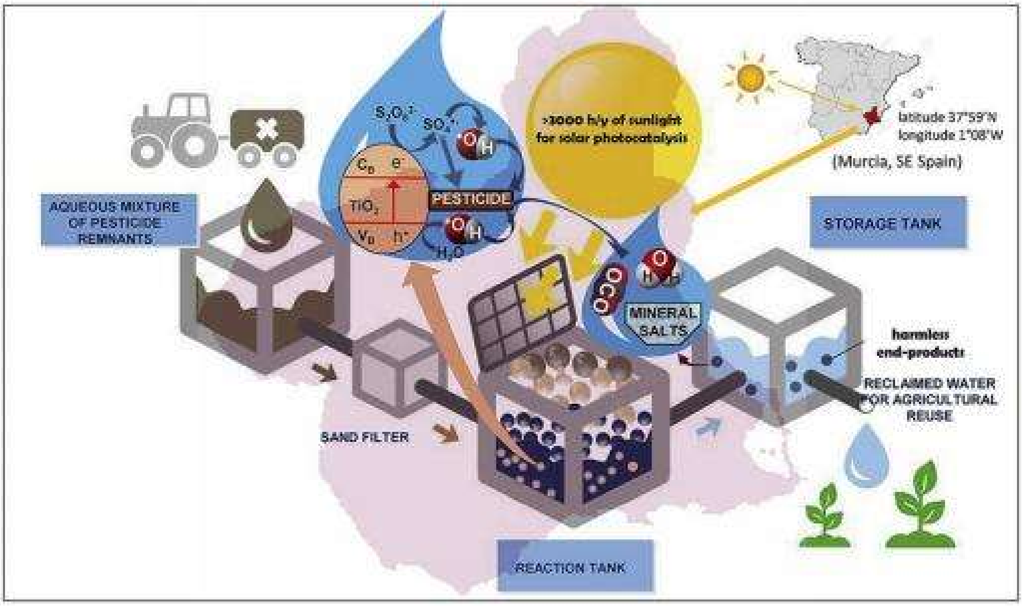


Figure 8. Photocatalytic solution for wastewater from murcia farm in Spain [16]

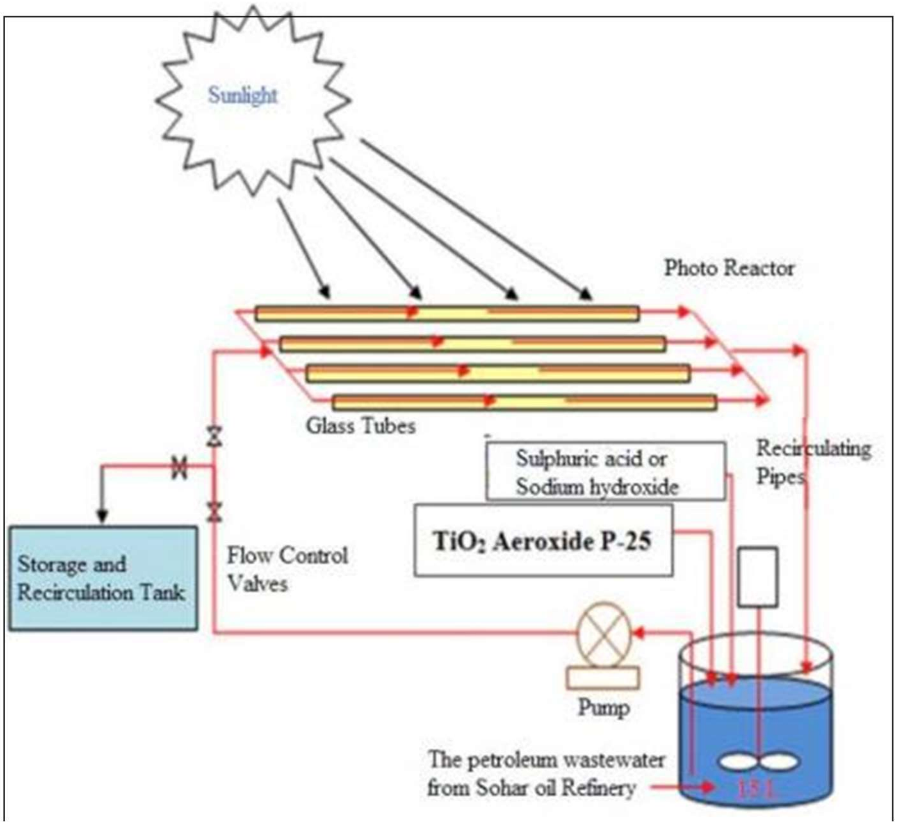


Figure 9. A schematic diagram of Photo-catalyst of TiO2 process [17]

In addition to its academic applications, photocatalytic wastewater treatment has gained significant traction within industrial sectors. Various industries, such as pharmaceuticals, textiles, and food processing, have integrated photocatalysis into their wastewater treatment methodologies. Specifically designed photocatalytic reactors are now being utilized on an industrial scale to address effluents contaminated with organic pollutants, dyes, and hazardous chemicals [13, 18, 19]. Through case studies and pilot-scale demonstrations, valuable insights have been gleaned regarding the practical implementation of photocatalytic processes in real-world contexts. Industrial experience underscores the critical nature of process optimization, reactor design, and catalyst selection in achieving both cost-effective and sustainable wastewater treatment solutions [18, 19].

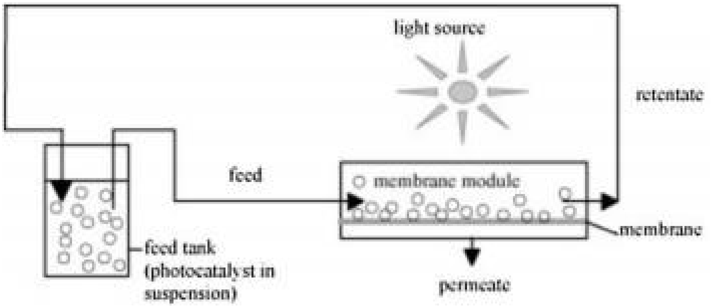


Figure 10(a). PMR utilizing photocatalyst in suspension: irradiation of the membrane module [19]

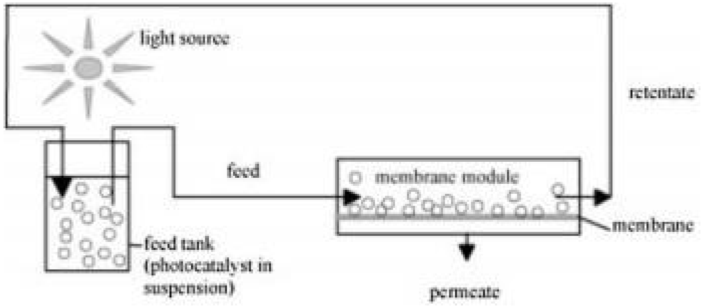


Figure 10(b). PMR utilizing photocatalyst in suspension: irradiation of the feed tank [19]

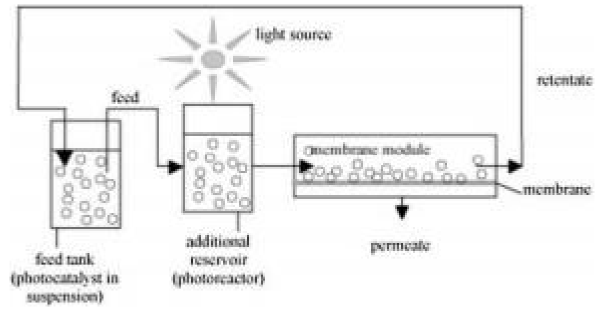


Figure 10(c). PMR utilizing photocatalyst in suspension[19]

What's more, combining photocatalysis with renewable energy sources such as solar energy and ultraviolet (UV) irradiation has attracted attention as a means to improve process sustainability and reduce energy consumption. Industrial applications have shown that decentralized wastewater treatment using solar photocatalytic reactors is feasible in remote or resource-limited areas [18, 19].

3.3.2. Design of Photocatalytic Purification Process for Agricultural Wastewater from Beerenberg Farm

To design an agricultural wastewater photocatalytic purification scheme suitable for Beerenberg Farm, It's needed to consider the climatic conditions, land availability, as well as the composition and volume of wastewater in the area. Based on the research findings, this report proposes to adopt a process using TiO2 photocatalyst for wastewater purification. Here is a brief description of the proposed scheme:

1) Overview:

The system is expected to occupy approximately 3000 square meters of land, which is of moderate scale and sufficient to handle the agricultural wastewater generated by a medium-sized farm. The system will primarily rely on solar energy as its power source, thus requiring ample sunlight in the region. Additionally, the setup may necessitate a water source for replenishing evaporative losses and maintaining system operation. To ensure continuous operation during overcast conditions or at night, the installation of solar energy storage batteries can be considered to provide electricity as needed.

Figrue 11. Photocatalytic sewage treatment system planning site

2) Equipment and Functions:

➢ Photovoltaic Panels: These panels will collect solar energy and convert it into electricity to power the entire system.

➢ Solar Reactor: This is the core component of the system, containing suspended TiO2 photocatalyst and wastewater. The reactor is designed to maximize the illuminated surface area to enhance photocatalytic efficiency.

➢ Stirrer: Used to ensure uniform distribution of TiO2 photocatalyst in the wastewater, enhancing reaction rates.

➢ Filtration System: Employed post photocatalytic reaction to remove suspended TiO2 particles and other solid impurities.

➢ Ultrafiltration Membrane: Used for further water purification, removing potentially incompletely degraded pesticide residues and other particles.

➢ Water Storage Tank: Storing treated water for subsequent quality testing.

➢ Control Unit: Monitors the operational status of the system, including parameters such as light intensity, temperature, pH, and water level.

➢

Table 4. Wastewater treatment system design proposal for Beerenberg Farm -Equipment table

Equipment	**Function**	**Size**	**Estimated Price**
Photovoltaic Panels	Solar energy conversion	Varies	\$3,000 - \$5,000
Solar Reactor	Photocatalytic reaction	10m x 5m	\$20,000 - \$30,000
Stirrer	Catalyst distribution	Varies	\$500 - \$1,000
Filtration System	Solid impurity removal	Varies	\$4,000 - \$60,000
Ultrafiltration Membrane	Further purification	Varies	\$10,000 - \$12,000
Water Storage Tank	Water storage and reuse	Varies	\$2,000 - \$3,000
Control Unit	System monitoring and regulation	Standard size	\$1,000 - \$3,000
		Total	\$40,500 - \$53,000
Prices for sewage treatment systems are provided by MDC WATER Limited, please refer to the website: https://waterfilter.net.au/ultrafiltration/			

The design of the entire system aims to achieve efficient, low-cost, and environmentally friendly agricultural wastewater treatment. By harnessing solar energy and TiO2 photocatalyst, the proposed scheme can effectively degrade organic pollutants in wastewater, thereby reducing environmental impact and providing a sustainable water reuse method for agricultural purposes. Furthermore, through proper design and operation, the system can be easily scaled up or down to meet the needs of farms of varying sizes.

Figure 12. Wastewater treatment system design proposal for Beerenberg Farm -Schematic drawing

3.3.3. Technical Economy and Feasibility Analysis

In the development of agricultural wastewater treatment plans, conducting technical and economic analyses, as well as calculating payback periods, are essential steps. These evaluations help assess the financial feasibility and sustainability of the proposed plans, offering crucial insights for decision-makers [20,21]. Technical and economic analyses play a key role in determining both the overall costs and benefits of the proposed plans. By examining expenses related to equipment, materials, energy, and labor, we can understand the total investment required [20]. Additionally, evaluating the advantages of the plan, such as reducing water pollution and enhancing water resource utilization efficiency, aids in assessing its economic viability.

The payback period calculation is a key aspect of both technical and economic analyses, signifying the duration needed to recoup expenses and commence earning profits from the investment [21]. A shorter payback period implies a more appealing scheme, enabling investors to swiftly attain a return on their investment. Consequently, by computing the payback period, this project can evaluate the rate of return on investment, thereby offering insights for investment decisions.

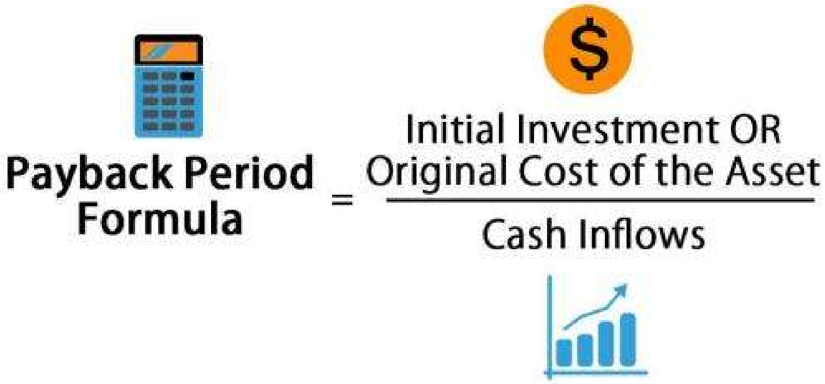


Figure 13. Calculation formula of payback period [21]

The economic feasibility and viability of the proposed photocatalytic wastewater treatment system for the Berenberg farm was evaluated through technical and economic analyses, including calculations of the payback period.

Based on the given estimates, including an initial investment of \$53,000, yearly operating expenses of 5%, and an annual discharge of 12,000 cubic meters of organic wastewater, as reported on Beerenberg Farm's official website [9, 10], coupled with an assumed 85% efficiency in purification and reuse, an economic analysis was undertaken.

The table below summarizes the key calculations:

Table 5. Return current calculation sheet of the project

Calculation Item	Calculation Formula	Result
Wastewater Treatment Revenue	Wastewater Volume x Treatment Cost	\$53,000
Annual Wastewater Volume	Annual Volume x Utilization Rate	10,200 m^3
Wastewater Treatment Cost	Wastewater Volume x Treatment Cost	\$25,500
Annual Net Profit	Treatment Revenue - Operating Cost	\$22,850
Payback Period	Initial Investment / Annual Net Profit	4.64years

According to the analysis, the project is expected to break even in about 4.64 years. This suggests that investing in a photocatalytic wastewater treatment system at Beerenberg Farm is financially viable and has the potential to generate returns in a relatively short period of time, making it an attractive option for sustainable agricultural wastewater management.

3.3.4. Comparison with Existing Wastewater Treatment Schemes

Aerobic lagoons represent the primary method of agricultural wastewater treatment in many farms across Southern Australia, including Beerenberg Farm [22]. These lagoons, which are large, shallow ponds, facilitate the treatment of wastewater through aerobic microbial activity. They serve as natural or man-made basins where aerobic bacteria decompose organic matter [22, 23]. Oxygen, essential for this process, is either naturally supplied through atmospheric diffusion or by mechanical aeration systems. Furthermore, the shallow depth of the lagoon allows sunlight to penetrate, encouraging algae photosynthesis, which contributes to oxygenation and nutrient removal. Due to their cost-effectiveness and low maintenance requirements, aerobic lagoons are widely favored for wastewater treatment in agricultural settings [23].

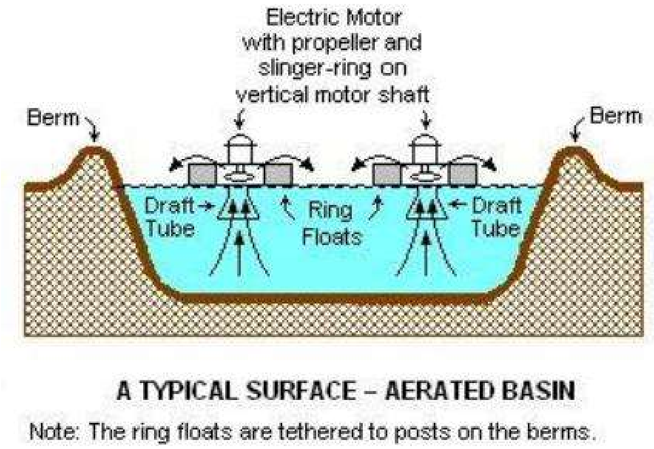


Figure 14. Atypical aerobic lagoon for sewage treatment [23]

Table 6. Comparison of Photocatalytic and Aerobic Lagoon Wastewater Treatment Methods

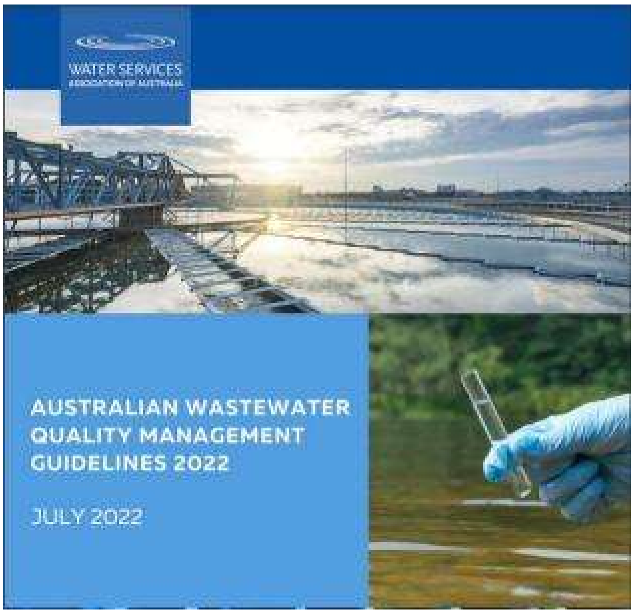
Aspect	Photocatalytic Treatment	Aerobic Lagoons
Treatment Efficiency	- Effectively degrades organic pollutants and pathogens. - Can target specific contaminants.	- Relies on microbial activity, may not effectively remove all contaminants. - Treatment efficiency can vary depending on environmental conditions.
Energy Requirement	- Requires electricity for operation. - Relatively low energy consumption.	- Minimal energy input required. - Relies on natural processes.
Land Requirement	- Requires moderate land area for installation of equipment.	- Requires large land area for construction of lagoons.
Maintenance	- Regular maintenance required for equipment such as reactors and filtration systems.	- Minimal maintenance required.
Operating Cost	- Higher initial investment. - Operational costs include electricity and maintenance.	- Lower initial investment. - Operational costs mainly include electricity for aeration.
Treatment Time	- Generally faster treatment time.	- Treatment may take longer due to reliance on microbial activity.
Flexibility	- Can be adapted to different scales and configurations. - Suitable for decentralized treatment.	- Limited flexibility, typically suited for large-scale applications.

Aerobic lagoons, although effective, have limitations, especially in terms of treatment efficiency and adaptability to different pollutants. Although they can effectively degrade organic matter, they may not adequately treat specific pollutants or pathogens in agricultural wastewater [23]. In addition, the reliance of digesters on natural processes means that treatment efficiency can be affected by environmental factors such as temperature and sunlight.

On the other hand, photocatalytic systems for treating agricultural wastewater provide a focused method for eliminating pollutants [14, 15, 17, 18]. These systems utilize photocatalysis to break down various organic pollutants and pathogens efficiently, offering superior treatment effectiveness when compared to aerobic lagoons. Nonetheless, they entail greater upfront costs and ongoing expenses due to the need for electricity to power the equipment and regular maintenance requirements.

3.3.5. Quality Assurance Program for Treated Wastewater

According to the Australian wastewater quality management guidelines (2022), it is crucial to guarantee the quality of treated wastewater from photocatalytic purification processes before considering it safe for human reuse [24]. Specific standards must be met by treated agricultural wastewater to ensure safety and environmental sustainability, including parameters like chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), pH levels, and the absence of harmful pathogens [25].



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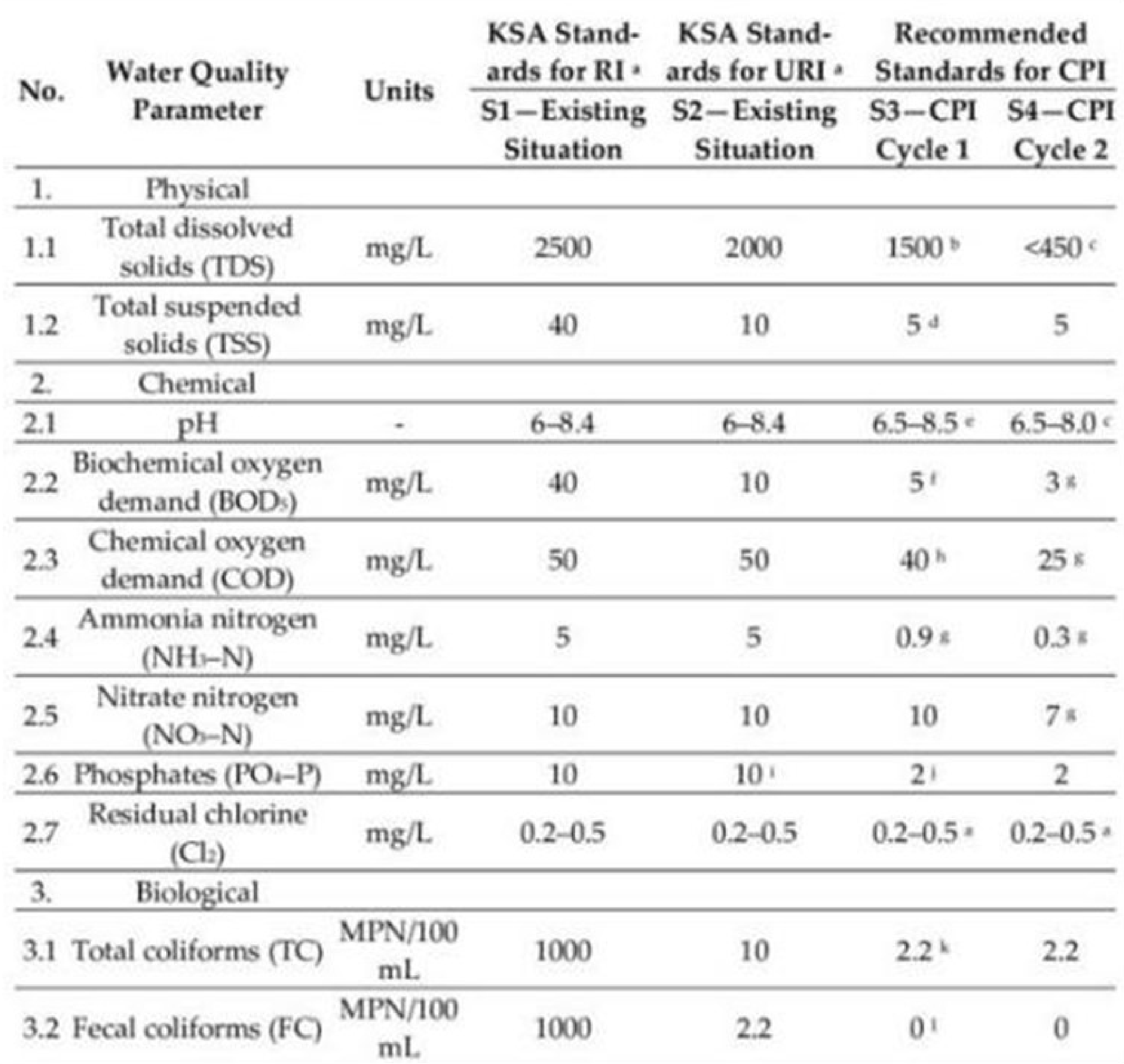
JULY 2022

Figure 15. Australian wastewater quality management guidelines [24]

Photocatalytic treatment systems must effectively reduce concentrations of organic pollutants, pathogens, and other contaminants to meet these standards. Regular monitoring and testing of treated wastewater is an important part of a quality assurance program. This includes sampling and analyzing treated wastewater to verify compliance with regulatory requirements and to ensure that it does not pose a hazard to human health or the environment. In addition, robust disinfection measures may be necessary to further safeguard the quality of treated wastewater before it is reused for purposes such as irrigation or groundwater recharge.

Table 7. Standards and guidelines for reuse of treated wastewater [25]



No.	Water Quality Parameter	Units	KSA Standards for RI ^{a}	KSA Standards for URI ^{a}	Recommended Standards for CPI	
			S1—Existing Situation	S2—Existing Situation	S3—CPI Cycle 1	S4—CPI Cycle 2
1.	Physical					
1.1	Total dissolved solids (TDS)	mg/L	2500	2000	1500 ^{b}	<450 ^{c}
1.2	Total suspended solids (TSS)	mg/L	40	10	5 ^{d}	5
2.	Chemical					
2.1	pH	-	6–8.4	6–8.4	6.5–8.5 ^{e}	6.5–8.0 ^{c}
2.2	Biochemical oxygen demand (BOD_5)	mg/L	40	10	5 ^{f}	3 ^{g}
2.3	Chemical oxygen demand (COD)	mg/L	50	50	40 ^{h}	25 ^{g}
2.4	Ammonia nitrogen (NH_3–N)	mg/L	5	5	0.9 ^{g}	0.3 ^{g}
2.5	Nitrate nitrogen (NO_3–N)	mg/L	10	10	10	7 ^{g}
2.6	Phosphates (PO_4–P)	mg/L	10	10 ^{i}	2 ^{j}	2
2.7	Residual chlorine (Cl_2)	mg/L	0.2–0.5	0.2–0.5	0.2–0.5 ^{a}	0.2–0.5 ^{a}
3.	Biological					
3.1	Total coliforms (TC)	MPN/100 mL	1000	10	2.2 ^{k}	2.2
3.2	Fecal coliforms (FC)	MPN/100 mL	1000	2.2	0 ^{l}	0

A range of measurement devices is used to ensure that treated wastewater meets quality standards. These instruments include spectrophotometers, which assess chemical parameters like COD and BOD, turbidity meters for measuring TSS levels, and pH meters to monitor acidity or alkalinity [24, 25]. Furthermore, microbial testing equipment, such as incubators and culture media, can be utilized to detect harmful pathogens. These devices are essential for accurately evaluating treated wastewater quality, ensuring it is safe for reuse in agriculture or environmental discharge.

These types of testing equipment is the same as the equipment in "3.2Agricultural wastewater detection and quantification", which can be found in the previous report for reference.

4. CONCLUSION

This study showcases the promising application of solar photocatalytic technology in treating agricultural wastewater, especially in environments like Beerenberg Farm. This technology offers a green and cost-efficient solution by employing TiO2 photocatalysts and solar reactors to effectively degrade pollutants and pathogens while minimizing reliance on conventional energy sources and operational expenses. Economic analysis demonstrates the system's viability, with an estimated payback period of around 4.64 years. In comparison to conventional methods such as aerobic lagoons, it exhibits superior treatment efficiency and adaptability. To ensure compliance with standards, a quality assurance plan involving regular monitoring and testing with spectrophotometers, turbidity meters, pH meters, and microbial testing equipment is imperative. In summary, solar photocatalytic systems present an innovative and sustainable strategy for agricultural wastewater treatment, contributing to environmental sustainability and paving the way for future advancements.

REFERENCES

[1] Liu, S. X. (2008). Food and agricultural wastewater utilization and treatment.John Wiley & Sons.

[2] Precedence Research. Water and Wastewater Treatment Market Size, Share, Trends Analysis Report by Product, by Application, by Region - Global Forecast,2021 - 2030. Retrieved fromhttps://www.precedenceresearch.com/water-and-wastewater-treatment-market.

[3] Arunkumar, T., Sathyamurthy, R., Denkenberger, D., & Lee, S. J. (2022). Solar distillation meets the real world: a review of solar stills purifying real wastewater and seawater. Environmental Science and Pollution Research, 29(16), 22860-22884.https://link.springer.com/article/10.1007/s11356-022-18720-2.

[4] Maridevaru, M. C., Sorrentino, A., Aljafari, B., & Anandan, S. (2022). Composites for Aqueous-Mediated Heterogeneously Catalyzed Degradation and Mineralization of Water Pollutants on TiO2 -. A Review. Journal of Composites Science, 6(11), 350.https://www.mdpi.com/2504-477X/6/11/350.

[5] Colacicco, A., & Zacchei, E. (2020). Optimization of energy consumptions of oxidation tanks in urban wastewater treatment plants with solar photovoltaic systems. Journal of Environmental Management, 276, 111353.https://www.sciencedirect.com/science/article/pii/S0301479720312792.

[6] Wetchakun, K., Wetchakun, N., & Sakulsermsuk, S. (2019). An overview of solar/visible light-driven heterogeneous photocatalysis for water purification: TiO2-and ZnO-based photocatalysts used in suspension photoreactors. Journal of industrial and engineering chemistry, 71, 19-49.https://www.sciencedirect.com/science/article/ pii/S1226086X 18314126.

[7] Pandey, A., Ahmed, S., Kumar, V., Singh, P., & Kothari, R. (2019). Solar Photocatalytic Treatments of Wastewater and Factors Affecting Mechanism: A Feasible Low-cost Approach. In Emerging Energy Alternatives for Sustainable Environment (pp. 399-426). CRC Press.https://www.researchgate.net/publication/314094103_Solar_Photocatalytic _Treatment s_of_Wastewater_and_Factors_Affecting_Mechanism_A_Feasible_Low-Cost_Appro ach.

[8] Wikipedia contributors. (2024, April 14). Beerenberg Farm. In Wikipedia. Retrieved April 14, 2024, from https://en.wikipedia.org/wiki/Beerenberg_Farm.

[9] Beerenberg Farm. (2024, April 14). Our sustainable choices. Retrieved from https://beerenberg.com.au/pages/our-sustainable-choices.

[10] Beerenberg Farm. (2024, April 14)). Collections. Retrieved from https://beerenberg.com.au/collections.

[11] Faithfull, N. T. (2002). Methods in agricultural chemical analysis: A practical handbook (pp. xxii+-266). https://www.cabidigitallibrary.org/doi/full/10.5555/20023165853.

[12] Leusch, F. D., Khan, S. J., Gagnon, M. M., Quayle, P., Trinh, T., Coleman, H., ... & Reitsema, T. (2014). Assessment of wastewater and recycled water quality: a comparison of lines of evidence from in vitro, in vivo and chemical analyses. Water research, 50, 420-431. https://www.sciencedirect.com/science/article/pii/S0043135413008622.

[13] Pandey, A. K., Kumar, R. R., Kalidasan, B., Laghari, I. A., Samykano, M., Kothari, R., ... & Tyagi, V. V. (2021). Utilization of solar energy for wastewater treatment: Challenges and progressive research trends. Journal of Environmental Management, 297, 113300. https://www.sciencedirect.com/science/article/pii/S03014797210136 21#tbl1.

[14] Kumar, A., Raizada, P., Singh, P., Saini, R. V., Saini, A. K., & Hosseini-Bandegharaei, A. (2020). Perspective and status of polymeric graphitic carbon nitride based Z-scheme photocatalytic systems for sustainable photocatalytic water purification. Chemical Engineering Journal, 391, 123496. https://www.sciencedirect.com/science/article/pii/ S1385894719329092.

[15] Lan, S., Yu, C., Sun, F., Chen, Y., Chen, D., Mai, W., & Zhu, M. (2022). Tuning piezoelectric driven photocatalysis by La-doped magnetic BiFeO3-based multiferroics for water purification. Nano Energy, 93, 106792. https://www.sciencedirect.com/science/article/pii/S2211285521010417.

[16] Kushniarou, A., Garrido, I., Fenoll, J., Vela, N., Flores, P., Navarro, G., Hellín, P., & Navarro, S. (2019). Solar photocatalytic reclamation of agro-waste water polluted with twelve pesticides for agricultural reuse. Chemosphere, 214, 839-845. https://doi.org/10.1016/j.chemosphere.2018.09.180.

[17] Aljuboury, D. A. D., Palaniandy, P., Aziz, H. B. A., & Feroz, S. (2015). Evaluating the TiO2 as a solar photocatalyst process by response surface methodology to treat the petroleum waste water. Karbala International Journal of Modern Science, 1(2), 78-85. https://doi.org/10.1016/j.kijoms.2015.10.006.

[18] Xie, Z., Peng, Y. P., Yu, L., Xing, C., Qiu, M., Hu, J., & Zhang, H. (2020). Solar -inspired water purification based on emerging 2D materials: status and challenges. Solar Rrl, 4(3), 1900400. https://onlinelibrary. wiley.com/doi/abs/10.1002/solr.201900400.

[19] Riaz, S., & Park, S. J. (2020). An overview of TiO2-based photocatalytic membrane reactors for water and wastewater treatments. Journal of industrial and engineering chemistry, 84, 23-41. https://www.sciencedirect.com/science/article/pii/S1226086X19306744.

[20] Abdel-Jawad, M., Ebrahim, S., Al-Tabtabaei, M., & Al-Shammari, S. (1999). Advanced technologies for municipal wastewater purification: technical and economic assessment. Desalination, 124(1-3), 251-261. https://www.sciencedirect.com/science/article/pii/S0011916499001101.

[21] Hajdasiński, M. M. (1993). The payback period as a measure of profitability and liquidity. The Engineering Economist, 38(3), 177-191. https://www.tandfonline.com/doi/abs/10.1080/00137919308903096.

[22] Radcliffe, J. C. (2022). Current status of recycled water for agricultural irrigation in Australia, potential opportunities and areas of emerging concern. Science of The Total Environment, 807, 151676. https://www.sciencedirect.com/science/article/pii/S0048969721067528#s0025.

[23] Membrane Chemicals. (2024, April 14). Floating Aerators. Retrieved from https://www.membranechemicals.com/water-treatment/floating-aerators/.

[24] The Australian Water Quality Centre. (2022). Australian wastewater quality management guidelines. Retrieved from https://www.wsaa.asn.au/publication/australian-wastewater-quality-management-guid elines-2022.

[25] Haider, H., AlHetari, M., Ghumman, A. R., Al-Salamah, I. S., Thabit, H., & Shafiquzzaman, M. (2021). Continuous performance improvement framework for sustainable wastewater treatment facilities in arid regions: Case of Wadi Rumah in Qassim, Saudi Arabia. International Journal of Environmental Research and Public Health, 18(13), 6857. https://www.mdpi.com/1660-4601/18/13/6857.