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Evaluation of wastewater treatment and solar energy-based solutions for enhanced water quality improvement

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ABSTRACT

The contamination of canals and rivers by wastewater is a growing environmental concern that threatens aquatic ecosystems and human health. This study employed a pre-post experimental design, alongside research and development methodologies, to analyze and design a small-scale solar-powered wastewater treatment system. The system was installed and demonstrated in the study area to assess its effectiveness. This research aims to analyze the quality of domestic wastewater sources and monitor the water quality in Samwang Canal, located in Bangbuathong Subdistrict, Nonthaburi province, Thailand. It explores the use of alternative energy solutions in designing a small-scale wastewater treatment model for demonstration purposes, specifically assessing the effectiveness of this treatment model. Results indicated that the water quality across the community's two main canals was below the surface water quality standards set by the National Environment Board (No. 8, 2537 BE). Key findings include average dissolved oxygen levels ranged from 0.45 to 0.60 mg/L, biochemical oxygen demand (BOD) levels were between 77.48 to 92.29 mg/L, oil and fat concentrations were between 32.50 to 96.9 mg/L. The small wastewater treatment system effectively reduced pollutants, achieving reductions of: oil and fat by up to 94.26%, BOD by 71.93%, and total dissolved solids by 54.09%. Additionally, oxygen levels (DO) in the canal improved from 0.88 mg/L to 3.98 mg/L over a 100-meter stretch. These results demonstrate that the solar-powered system is an effective and viable solution for treating wastewater in similar canal systems. To address water quality issues further, it is recommended to reduce organic loads at primary sources by installing on-site treatment systems. Local authorities should also conduct regular training and community education on wastewater management, while community-led monitoring activities are essential for continuous water quality improvement.

Keywords: wastewater management, natural energy resources, environment, biochemical oxygen demand, dissolved oxygen.

INTRODUCTION

The contamination of water bodies, particularly canals and rivers, by untreated or poorly managed wastewater poses a significant threat to environmental sustainability and public health (Lema, 2024). This issue is particularly pressing in urban and semi-urban areas, where wastewater from domestic sources often exceeds the capacity of existing treatment systems (Nuwanka and Gunathilaka, 2023). While traditional wastewater treatment methods have been widely implemented, they often rely on energy-intensive processes and centralized infrastructure, which can be both costly and inaccessible to smaller communities (Sangamnere et al., 2023). Despite numerous studies on water pollution and wastewater treatment, a significant research gap exists in developing small-scale, decentralized systems powered by renewable energy sources (Ali et al., 2023; Sharma et al., 2023; Mathew et al., 2024). This study addresses this gap by designing and demonstrating a solar-powered wastewater treatment system tailored to local conditions. By focusing on canals in Nonthaburi Province, Thailand, the study contributes to the broader understanding of how alternative energy solutions can be integrated into wastewater management practices to enhance sustainability and efficiency.

The integration of solar energy in wastewater treatment systems represents a paradigm shift toward sustainable and environmentally friendly solutions (Choi et al., 2024). Solar energy, as a renewable resource, offers several advantages: it is abundant, cost-effective in the long term, and reduces reliance on non-renewable energy sources that contribute to greenhouse gas emissions (Adam et al., 2023). For regions with high solar irradiance, such as Thailand, harnessing solar power for wastewater treatment is particularly relevant. This approach not only lowers operational costs by minimizing energy expenses but also ensures the scalability of treatment systems in off-grid or resource-limited areas. Furthermore, solar-powered systems align with global efforts to reduce carbon footprints and promote renewable energy adoption (Pandey et al., 2021). By emphasizing the use of solar energy, this study not only highlights the potential for technological innovation in wastewater treatment but also underscores its role in achieving sustainable development goals.

The contamination of canals and rivers by wastewater has emerged as a critical environmental challenge, posing significant threats to aquatic ecosystems and public health (Pal et al., 2014). Effective wastewater treatment is indispensable for mitigating the detrimental impacts of pollutants, including heavy metals, excess nutrients, and pathogenic microorganisms, which contribute to the degradation of water quality (Singh et al., 2022). Conventional treatment methods often fall short of addressing the intricate and site-specific nature of wastewater discharges into natural water bodies, necessitating the adoption of innovative and sustainable solutions (Gogate and Pandit, 2004). As urbanization and industrial activities intensify, the demand for efficient wastewater management systems tailored to the unique hydrological and ecological conditions of canals and rivers becomes increasingly urgent (Sharma et al., 2019). This study investigates the deployment of advanced treatment technologies and integrative policy frameworks in Thailand, focusing on restoring and preserving the ecological integrity of the Samwang Canal, which has been severely impacted by wastewater pollution.

The Bangbuathong Subdistrict in Thailand covers 29.7 square kilometers and includes extensive wetlands near the river. Historically, the land was highly fertile, making it ideal for agriculture. However, urban development has led to population growth and the establishment of numerous housing estates – 42 developments housing 1.329 establishments – in the district. The area contains 13 canals that are interconnected with the Tha Chin River, serving purposes such as irrigation, transportation, and water drainage during heavy rains.

Currently, these canals face issues such as water quality degradation and blockage from aquatic plants, impacting water flow and ecosystem health. Sustainable wastewater management practices, such as those seen in East Africa, emphasize community-level management systems, including sump drains that direct water into canals using locally available technology (Bakir, 2001). Effective wastewater management relies on indicators that cover economic, environmental, and social aspects (Starkl et al., 2022).

Previous studies on treating wastewater with advanced oxidation processes (AOPs) demonstrated that solar energy, combined with catalysts like TiO_2/UV and TiO_2/H_2O_2/UV, can significantly reduce COD levels and remove contaminants, achieving a 46–54% reduction in COD and 24–34% pest removal (Moreira et al., 2012).

Samwang Canal is one of the 13 canals in Bangbuathong Subdistrict, stretching over 3.87 km. The canal is classified as surface water type 5 (PCD 2553) and requires restoration to improve its quality for navigation and agricultural use. Given the current dependence on conventional power sources, this research seeks to apply natural energy resources to wastewater treatment in the canal. The aim is to develop sustainable wastewater management strategies that can be used to rehabilitate water sources in the Bangbuathong area and similar canals across the country. This study aims to identify sewage sources and assess the water quality in Samwang Canal to facilitate the design of an effective water management system for the canal. It would develop a wastewater treatment system that utilizes natural energy sources for sustainable water management and assess the system's effectiveness in improving water quality. The research would focus on sampling and monitoring water quality within the Bangbuathong Sub-district and include system design, testing, and community outreach at the Environmental Science Analysis Laboratory, Suan Sunundha Rajabhat University. The study measured the wastewater entering the canal, analyze water quality along a 1-kilometer section, and evaluated key parameters such as turbidity, color, pH, and dissolved oxygen. The effectiveness of the wastewater management system in purifying the canal to make the water odorless and clear would also be tested. Community engagement and training initiatives would promote sustainable canal use, with the entire research process scheduled for completion within six months.

RESEARCH METHODOLOGY

The research methodology involved several key stages to assess and improve water quality in the canal. First, water samples were collected from communities along a 1-km stretch of the canal, with sampling points located upstream, midstream, and downstream. Standard methods were used to analyze water quality, focusing on five basic parameters: pH, suspended solids (SS), total dissolved solids (TDS), biochemical oxygen demand (BOD), and oil and grease. This preliminary analysis provided a baseline for water quality, as illustrated in Figure 1, which demonstrates water quality using natural energy.

Samples were collected in clean, sterile containers, and pH readings were taken immediately on-site to ensure accuracy and prevent alterations due to storage. The pH of the water was measured using a calibrated digital pH meter (HANNA HI98107, Italy). SS were measured using the gravimetric method. Water samples were filtered through pre-weighed filter papers (MilliporeSigma filters, Germany), which were then dried at 103–105 °C to a constant weight, and the increase in weight was used to calculate the SS concentration. TDS) were measured using a calibrated TDS meter (hi98302 Hanna, Italy). Water samples were analyzed directly on-site, with the meter providing a reading in milligrams per liter (mg/L) based on the electrical conductivity of the dissolved ions in the water. The BOD method involves collecting water samples and measuring the DO levels before and after a five-day incubation period. Initially, the water sample is placed in a sealed, airtight bottle, and the initial DO concentration is recorded. The sample is then incubated at 20 °C for five days in the dark to prevent photosynthesis. After the incubation period, the final DO level is measured. The difference between the initial and final DO concentrations indicates the amount of oxygen consumed by microorganisms as they decompose organic material in the water. This difference is used to calculate the BOD value, which reflects the water's organic pollution level. The hexane extraction method for oil and grease analysis involved adding a known volume of hexane to the water sample in a separatory funnel (Mohana et al., 2023). The mixture was shaken thoroughly to extract the oil and grease into the hexane layer, which was then separated and evaporated using a rotary evaporator. The remaining residue was weighed to determine the concentration of oil and grease in the sample. The study focused on identifying the sources of wastewater and the activities contributing to its discharge into the canal, with samples collected from these sources. Sampling locations were selected to represent approximately 30% of all discharge points, supplemented by 3–5 random sampling points along the canal. Additionally, the flow rate of the discharged water was measured. The canal, Khlong Samwang, has a length of 3.870 kilometers, a width of approximately 5–7 meters, and a depth of about 2.5–3.0 meters from the canal banks. It flows through the Bang Bua Thong subdistrict, where the primary land

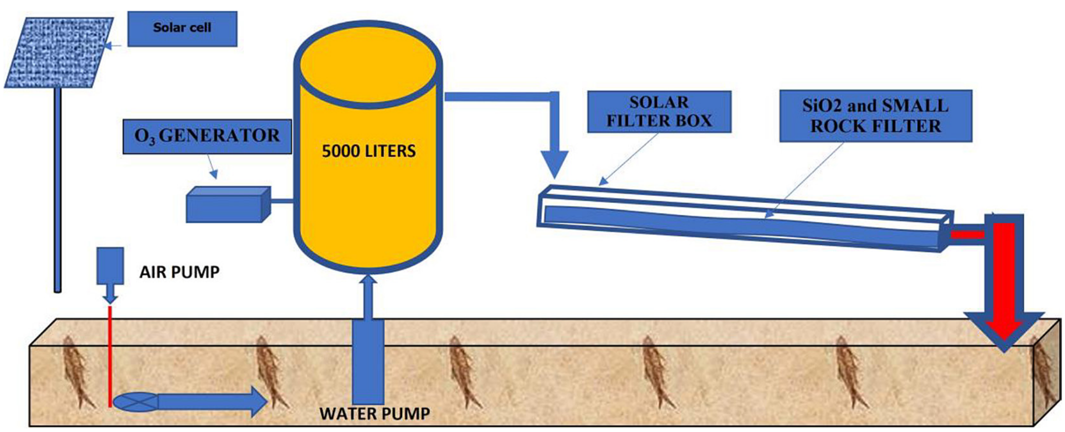

Figure 1. The wastewater treatment system in the canal powered by natural energy

use is residential, with housing estates that have been established for over 10 years.

Next, data analysis informed the design of a wastewater treatment system that harnesses natural energy sources to generate electricity and mechanical energy, also depicted in Figure 1. Following this, the designed wastewater management system was installed along the 1-km canal stretch. Physical and biological parameters, including pH, SS, TDS, BOD, oil and grease, and dissolved oxygen (DO), were monitored to evaluate the system's effectiveness. Water samples were collected three times over a two-month period, allowing researchers to study the system's impact on water quality.

Lastly, the research emphasized public awareness and involvement in wastewater management. The findings were published to inform and engage the community, while monitoring efforts were extended to a second canal to enhance public participation in water quality surveillance and improve understanding of wastewater treatment practices. The analysis was carried out at the Environmental Science Laboratory of Suan Sunandha Rajabhat University.

RESULTS

The water quality in Samwang Canal was initially found to fall below the surface water quality standards established by Thailand's National Environmental Board Announcement No. 8 (1994), issued under the National Environmental Quality Promotion and Maintenance Act B.E. 2535, with levels of key indicators measuring 2–3 times lower than the recommended standards. The details of analysis results presented here in specific sections.

Wastewater flow rate measurement

The flow rate of wastewater discharged into Samwang was measured at six sampling points along a 1-km section of the canal. Measurements were taken at the end of discharge pipes using calibrated volumetric equipment and a timer to calculate the flow rate. The average daily wastewater flow rates at each location are summarized in Table 1.

Measurement of dissolved oxygen in the field

Dissolved oxygen analysis results in Samwang

The dissolved oxygen levels were measured at three locations (upstream, midstream, and downstream) along Khlong Samwang for seven weeks. The results are summarized in Table 2.

Additionally, the DO levels were analyzed at six wastewater discharge points in the Bua Thong Thani area, as shown in Table 3.

The dissolved oxygen (DO) levels across Samwang were consistently lower than the standard range (2–6 mg/L), indicating severe

Table 1. Average daily wastewater flow rates discharged into the canal

Sampling point	Average flow rate (m^3/day)
1. Bua Thong Thani Soi 1–4	1.590
2. Bua Thong Thani Soi 5–6	1.924
3. Bua Thong Thani Soi 7–8	1.561
4. Bua Thong Thani Soi 9–10	1.159
5. Bua Thong Thani Soi 11–12	1.912
6. Bua Thong Keha	1.654
Average	1,633.34

Table 2. Dissolved oxygen levels in Samwang

Week	Upstream (mg/L)	Midstream (mg/L)	Downstream (mg/L)
1	0.15	0.12	0.21
2	0.7	0.6	0.4
3	0.9	0.8	0.4
4	0.7	0.5	0.4
5	0.3	0.6	0.3
6	0.4	0.3	0.7
7	0.8	0.2	0.8
Average	0.56	0.45	0.46
Standard (mg/L)*	2–6	2–6	2–6

Note: Standard values are based on surface water quality standards set by the National Environmental Board mentioned above.

oxygen depletion throughout the canal, likely due to organic waste accumulation. The highest DO values were observed at the discharge point in Soi 9–10, attributed to a functional wastewater treatment system with aeration. The BOD levels exceeded the standard range (1.5–4 mg/L) across all sampling locations, indicating high levels of organic pollution, rendering the water unsuitable for drinking, agriculture, or industrial use. These findings highlight the need for improved wastewater treatment measures and effective management to mitigate pollution in Khlong (canal) Samwang.

From Table 4–5, the average BOD values in Khlong (canal) Samwang range between 80.17–101.30 mg/l, significantly exceeding the surface water quality standard for Type 5 water (1.5–4 mg/l). This reflects a high accumulation of biodegradable organic waste, leading to severe pollution. The anaerobic decomposition of

Table 3. Dissolved oxygen levels at wastewater discharge points

Week	Soi 1–4	Soi 5–6	Soi 7–8	Soi 9–10	Soi 11–12	Bua Thong Keha
1	0.5	0.81	1.23	1.54	0.3	0.38
2	0.6	0.7	0.5	1.9	0.3	0.6
3	0.3	0.4	0.6	0.9	0.3	0.4
4	0.4	0.4	0.8	0.4	0.4	0.5
5	0.4	0.4	0.8	1.1	0.5	0.4
6	1.3	0.3	0.6	1.4	0.5	0.6
7	0.2	0.6	0.8	1.4	0.6	0.3
Average	0.53	0.52	0.76	1.23	0.41	0.45
Standard (mg/L)*	2–6	2–6	2–6	2–6	2–6	2-6

Table 4. BOD Levels in Samwang.

Week	Upstream (mg/L)	Midstream (mg/L)	Downstream (mg/L)
1	96.5	99.7	98.1
2	98.1	98.5	99.4
3	97.0	95.4	96.4
4	97.4	108.2	99.6
5	89.2	91.0	89.0
6	83.8	92.2	67.0
7	94.0	96.0	97.0
Average	93.71	97.29	92.36
Standard (mg/L)*	1.5–4	1.5–4	1.5–4

Note: Standards are based on surface water quality standards outlined by the National Environmental Board (1994).

Table 5. Results of BOD (biochemical oxygen demand) analysis by discharge points into Samwang

Week	Bua Thong Thani Soi 1–4	Bua Thong Thani Soi 5–6	Bua Thong Thani Soi 7–8	Bua Thong Thani Soi 9–10	Bua Thong Thani Soi 11–12	Bua Thong Keha
1	89.2	88.2	74.6	93.5	99.1	84.3
2	84.6	84.2	78.7	96.4	80.6	79.9
3	87.6	95.5	86.3	97.1	94.4	88
4	99.0	75.5	84.6	91.0	96.2	92
5	84.0	97.6	93.2	86.4	121.0	53.0
6	115.2	95.4	61.0	69.2	109.0	81.6
7	89.6	102.0	86.6	75.2	108.8	57.6
Average	92.74	91.20	80.71	86.97	101.30	76.63
Standard (mg/l)	1.5–4	1.5–4	1.5–4	1.5–4	1.5–4	1.5–4

organic matter results in the water becoming black and emitting a strong odor of hydrogen sulfide (H2S).

Oil and grease analysis

The analysis of oil and grease in the water was conducted using the hexane extraction method in an environmental laboratory. The results are presented in Tables 6 and 7. From Tables 6–7, it is evident that the levels of oil and grease in Khlong (canal) Samwang are relatively high, averaging 24.76–34.31 mg/l. These pollutants originate from household activities and represent a significant water quality indicator. The large molecular size of oil and grease makes microbial decomposition more challenging, especially under anaerobic conditions, leading to extended periods required for treatment.

Total suspended solids and dissolved solids analysis

The analysis was conducted using filtration and dry evaporation methods at 103–105 °C in an environmental laboratory. The results are presented in Tables 8–11.

Furthermore, it was observed that the water source had the discharge of waste containing pollutants such as phosphate and nitrogen. The activities responsible for these two pollutants are washing with detergents or activities that use nitrogen fertilizers for soil enrichment or other household activities. Both of these substances can be reused as food sources for plants. However, the harmful effect on the water source is that these substances accelerate the growth of aquatic plants or water weeds. Therefore, it is observed that there is rapid growth of water hyacinth in this water source (Appendix 1).

Wastewater management system design

From Figure 1, it can be explained that the wastewater treatment system designed as a functional model. The model works as follows:

1. Water is pumped from the canal and aerated using an oxygenator with an oxygen supply rate of 200–400 liters per minute, powered by solar energy. Oxygen is added to 1.000 liters of wastewater to increase dissolved oxygen levels to 5–6 mg/l. The process takes 30–60 minutes.

Table 6. Results of oil and grease analysis in Khlong Samwang

Week	Upstream 1	Upstream 2	Upstream 3
1	31.0	31.4	32.5
2	29.5	29.5	33.9
3	29.7	35.6	33.5
4	33.5	31.5	33.2
5	36.0	31.6	33.3
6	35.5	32.2	29.9
7	33.1	35.8	31.2
Average	32.61	32.51	32.50

Table 8. Results of pollution level measurements in terms of suspended solids in Samwang Canal

Week (mg/l)	Upper stream	Middle stream	Lower stream
1	104.5	112.1	106.4
2	99.5	99.8	105.6
3	89.5	102.2	102.2
4	88.6	105.4	104.8
5	94.1	106.6	101.6
6	87.7	99.8	102.6
7	88.5	87.9	99.4
Average	93.20	101.97	103.23

Table 7. Results of oil and grease analysis at discharge points into Khlong Samwang

Week	Bua Thong Thani Soi 1–4	Bua Thong Thani Soi 5–6	Bua Thong Thani Soi 7–8	Bua Thong Thani Soi 9–10	Bua Thong Thani Soi 11–12	Bua Thong Keha
1	30.5	25.8	29.4	35.5	33.9	31.2
2	30.9	24.6	33.4	36.6	33.2	30.3
3	31.5	25.5	32.2	33.5	33.5	29.9
4	29.4	23.1	30.5	34.5	33.3	28.4
5	29.1	20.4	31.1	35.5	33.9	27.4
6	31.4	29.5	34.2	33.4	34.4	25.4
7	32.5	24.4	33.2	31.2	31.2	31.5
Average	30.76	24.76	32.00	34.31	33.34	29.16

Table 9. Analysis of suspended solids at discharge points into the Samwang Canal

Week	Bua Thong Thani Soi 1–4	Bua Thong Thani Soi 5–6	Bua Thong Thani Soi 7–8	Bua Thong Thani Soi 9–10	Bua Thong Thani Soi 11–12	Bua Thong Kehah
1	84.6	88.5	87.9	105.7	110.6	87.6
2	88.6	87.4	91.0	101.2	105.5	68.6
3	91.5	76.5	95.6	102.6	104.1	48.5
4	87.6	78.4	88.0	102.1	104.2	91.5
5	88.6	79.0	101.5	102.6	103.3	88.5
6	54.4	89.1	84.6	99.4	89.5	76.5
7	94.1	90.0	88.9	89.6	99.5	69.5
Average	84.2	84.20	84.13	91.07	100.46	102.39

2. The water, now containing 5–6 mg/l of dissolved oxygen, is pumped to add ozone. This addition facilitates the oxidation reaction between organic substances and ozone gas, reducing pollutants like hydrogen sulfide and BOD in the water. Ozone is added at 1.000 mg/min, with a duration of 60 minutes.
3. The water, after ozone treatment, is released into a drainage system containing washed gravel. The gravel, with a high silica content, helps in oxidation reactions under natural ultraviolet light, further reducing water contamination.

Table 10. Measurement results of pollution levels in terms of total dissolved solids in Samwang Canal

Week (mg/l)	Upper stream	Middle stream	Lower stream
1	312	274	289
2	330	333	298
3	305	257	264
4	247	297	312
5	255	301	266
6	221	303	267
7	229	301	265
Average	271	295	280

The results show that the model was effective in treating contaminants in the water (Table 12). Oil and grease levels were reduced by 94.26%, BOD by 71.93%, and dissolved oxygen levels increased from 0.88 mg/l to 3.98 mg/l. Thus, the water quality in the canal can be restored as follows. The water quality data from the Klong (canal) Samwang canal revealed that the pollution load, indicated by the high BOD, is a major cause of water degradation. When considering other water quality indicators, such as dissolved oxygen, the levels were below the standards for Class 2–3 surface water, as specified by the Thailand, National Environment Board Notification No. 8 (1994). The oil and grease levels also exceeded the standards. To address water quality issues, a combination of educational and mechanical interventions focusing on increasing oxygen levels should be implemented. Local authorities can take several actions to improve the situation: Residential areas should install centralized wastewater treatment systems, incorporating grease traps and biological treatment systems with aeration, while homeowners should implement on-site treatment systems such as grease traps and septic tanks. Small businesses that generate wastewater

Table 11. Measurement results of total dissolved solids at discharge points into the Samwang Canal

Week	Bua Thong Thani Soi 1–4	Bua Thong Thani Soi 5–6	Bua Thong Thani Soi 7–8	Bua Thong Thani Soi 9–10	Bua Thong Thani Soi 11–12	Bua Thong Kehah
1	258	306	198	241	302	264
2	269	701	263	355	381	273
3	268	346	118	190	248	275
4	264	333	128	198	274	270
5	292	333	175	211	340	284
6	253	345	177	170	282	259
7	263	340	186	205	247	255
Average		267	386	178	224	296

Table 12. Shows the average water quality analysis results from the model tests

Water quality index	Before treatment	After ozone addition	After gravel filtration	Treatment efficiency
pH	7.21	7.1	7.24	–
Total dissolved solids (TDS)	280.90 mg/l	230.1 mg/l	228.9 mg/l	21.42%
Suspended solids (SS)	45.2 mg/l	32.1 mg/l	32.1 mg/l	28.90%
Oil & grease	13.54 mg/l	1.85 mg/l	0.77 mg/l	94.26%
Dissolved oxygen (DO)	0.88 mg/l	5.6 mg/l	3.98 mg/l	–
Biochemical oxygen demand (BOD)	60.33 mg/l	19.20 mg/l	16.93 mg/l	71.93%
Phosphate (PO_4)	4.84 mg/l	3.85 mg/l	2.58 mg/l	46.63%

must adhere to regulations, with industrial factories complying with the Industrial Factory Act, and small household businesses receiving education on proper wastewater management practices before discharging into the canal. Additionally, community measures should involve periodic training for residents living along the canal on wastewater management, along with the establishment of regular water quality monitoring activities within the community.

This approach included mechanical oxygenation methods, oxidizing techniques, and ozonation, all powered by solar energy. Solar cells supplied energy for oxygen generation, and a photochemical process using UV light further boosted oxygen production. The intervention yielded substantial improvements in water quality, including a 94.26% reduction in oil and grease, a 71.93% reduction in BOD, and a 21.42% reduction in total dissolved solids (TDS). Notably, the average oxygen content in the water rose from 0.88 mg per liter to 3.98 mg per liter, resulting in significantly clearer water.

DISCUSSION

The literature review highlights that the effectiveness and sustainability of wastewater management depend on social, economic, and environmental factors, requiring collaboration between technology transferring system and the public (Padilla-Rivera et al., 2016). This collaborative approach is vital to preventing pollution and addressing environmental challenges (Yang et al., 2017). Thailand has established water quality standards based on intended water use: Category 1 water is clean and suitable for all uses without treatment; Category 2 requires sterilization for uses like fishing or swimming; Category 3 is suitable for irrigation or agriculture after treatment; Category 4 needs treatment before industrial use; and Category 5 is contaminated, suitable only for communication purposes. Wastewater treatment methods include physical treatment for removing solid contaminants, chemical treatment for neutralizing pH levels and removing heavy metals, biological treatment using microbes to break down organic matter, and physical-chemical treatment that combines these approaches for purification (Sonune and Ghate, 2004). Popular treatment technologies vary by scale; small-scale methods like septic tanks or anaerobic filters serve homes and can remove up to 60% of contaminants, while medium- to large-scale systems, such as activated sludge or rotating biological discs, are used for larger communities, offering high efficiency but with increased cost, making them suitable for municipal and provincial treatment plants (Thalla and Devika, 2024). Related studies demonstrate various innovative approaches to sustainable wastewater treatment, focusing on energy efficiency and community-based management. Many researchers explored using solar energy for water treatment in their study (Pandey et al., 2021). They successfully utilized solar panels to power mechanical aerators, improving water oxygen levels and showcasing solar energy's potential as a primary energy source for aeration. Similarly, Bakir (2001) examined sustainable water and waste management in East Africa, emphasizing the need for on-site treatment systems within communities (Bakir, 2001). His findings indicated that treating wastewater locally, using accessible technologies before releasing it into public systems, can enhance water quality in community-based settings. The research by Muga and Mihelcic (2008) underscored key factors in sustainable wastewater management, highlighting economic costs, environmental benefits (such as reducing biochemical oxygen demand and other pollutants), and the importance of community involvement in wastewater management (Muga and Mihelcic 2008). Building on solar energy applications, Asadi et al. (2013) demonstrated the effectiveness of solar energy in wastewater treatment, achieving over 86% reduction in chemical oxygen demand through solar-powered distillation, which indicates solar distillation's efficiency in contaminant reduction (Asadi et al., 2013). Moreira et al., 2012 combined biological and solar treatments, testing advanced oxidation processes with titanium dioxide (TiO_2) as a catalyst under solar energy (Moreira et al., 2012). This method showed a COD reduction of 46–54% and helped eliminate harmful pathogens, proving that a combined approach can enhance treatment efficacy. Mo and Zhang (2013) took an integrated approach, examining the reuse of energy, minerals, food, and water in large-scale wastewater treatment (Mo and Zhang, 2013). They demonstrated that treated wastewater could serve household purposes, while byproducts like biogas and nutrients could be repurposed for electricity generation and soil enrichment, respectively. Their study highlights the potential of wastewater to be a sustainable resource when employing the right technologies. The study illustrates that effective wastewater management benefits from an integrated approach that incorporates technological advancements, optimized processes, and consideration of social and economic impacts. This approach aligns with the work of researchers, who stress the importance of leveraging nature-based solutions in wastewater treatment (Pastor-Lopez et al., 2024). The study highlights two primary methods: generating electricity through mechanical treatment and employing solar energy with ultraviolet light to drive photochemical reactions that enhance oxidation, thereby increasing water's oxygen content. These methods parallel findings by Moreira et al. (2012), who also advocate for using natural forces in wastewater treatment (Moreira et al., 2012). Despite the promising results, the study underscores the need for further exploration and refinement of these techniques to fully realize their potential and effectiveness in sustainable wastewater management.

The analysis of wastewater and water quality parameters in the Samwang Canal reveals critical insights into pollution levels and treatment efficiencies. The study highlights that the average daily wastewater flow rates range from 1.159 to 1.924 m^3/day across various discharge points, with an average of 1,633.34 m^3/day. Dissolved oxygen (DO) levels (Table 2) were significantly below the standard of 2–6 mg/L across upstream, midstream, and downstream locations, with averages of 0.56, 0.45, and 0.46 mg/L, respectively, indicating severe oxygen depletion. Similarly, DO levels at discharge points (Table 3) averaged between 0.41 and 1.23 mg/L, underscoring poor oxygenation near outflows.

BOD levels (Tables 4 and 5) far exceeded the acceptable range of 1.5–4 mg/L, averaging 93.71–97.29 mg/L across the canal and 76.63–101.30 mg/L at discharge points, signifying high organic pollution. Oil and grease levels (Tables 6 and 7) averaged 32.5–34.31 mg/L in upstream areas and 24.76–33.34 mg/L at discharge points, surpassing the standard of 1.5–4 mg/L. Suspended solids (Tables 8 and 9) ranged from 84.2 to 102.39 mg/L at discharge points and 93.20 to 103.23 mg/L in the canal, further contributing to water quality degradation. TDS measurements (Tables 10 and 11) revealed high levels across all sites, with averages ranging from 271 to 295 mg/L in the canal and 178 to 386 mg/L at discharge points.

Table 12 demonstrates the potential of treatment methods, where ozone addition and gravel filtration reduced TDS by 21.42% and suspended solids by 23.85%. However, post-treatment pH remained stable around 7.2, suggesting minimal impact on acidity levels. The findings indicate that pollution in the Samwang Canal primarily arises from untreated organic waste, oil, and grease, leading to poor oxygenation and excessive solid contaminants. These results emphasize the need for improved wastewater treatment strategies and stricter pollution control measures to meet environmental standards and enhance aquatic ecosystem health.

The water quality data from the Khlong (canal) Samwang canal revealed a significant pollution load, primarily driven by high BOD levels, which contribute to water degradation. Other water quality indicators, such as dissolved oxygen, were found to be below the standards for Class 2–3 surface water, as specified by the National Environment Board Notification No. 8 (1994), and oil and grease concentrations exceeded the allowable limits. To improve water quality, several measures should be implemented. In residential areas, subdivisions should adopt centralized wastewater treatment systems with grease traps and biological treatment systems equipped with aeration, while homeowners should install on-site treatment systems like grease traps and septic tanks. Small businesses generating wastewater should comply with the Industrial Factory Act, and small household businesses need to be educated on proper wastewater management before discharging waste into the canal. Additionally, local authorities should provide periodic training on wastewater management for residents living along the canal and establish continuous water quality monitoring activities within the community to ensure ongoing improvements.

CONCLUSIONS

The restoration of water quality in Samwang Canal has been effectively achieved through community-led initiatives and the implementation of targeted wastewater management systems. Key measures included mitigating organic pollution from local sources and introducing suitable wastewater treatment solutions, such as grease traps, septic systems, and biological air-based treatment systems for individual households. The installation of on-site treatment technologies, including grease traps and anaerobic septic filters, can further address waste at its origin. Moreover, educating residents along the canal through ongoing training and awareness programs on wastewater management is essential for fostering sustainable practices. Continuous monitoring of water quality, supported by community engagement, will be pivotal in tracking improvements and ensuring the long-term sustainability of water quality in the canal.

To improve wastewater management in the canals, strengthening community involvement is essential. Increasing local participation in monitoring and protecting water quality can be achieved by implementing a more effective water quality surveillance system. This approach can raise awareness and foster engagement among residents. Additionally, continuous education on wastewater treatment technologies should be provided to the community. By keeping residents informed about advanced treatment methods, the system can remain efficient and well-managed over time. Furthermore, ensuring a reliable energy supply for treatment systems is crucial. Although natural energy sources like solar power are beneficial, they may encounter limitations, especially during the rainy season. Therefore, having a backup power source is necessary to maintain uninterrupted operation of the treatment systems when sunlight is insufficient.

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