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Article

Economic Analysis of The Innovative Eco-Biofilter /Membrane Bioreactor (MBR) System for Community Wastewater Recycling

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Abstract. A prototype Eco-biofilter/MBR (Membrane Bioreactor) system has been developed and installed at a community in Chiang Rak Yai Sub-district, Sam Khok District, Pathum Thani Province, Thailand for community wastewater treatment and recycling. This research aims to investigate the performance of Eco-biofilter/MBR system, as well as the economic analysis of willingness to pay for wastewater treatment. A novel porous baked clay biofilter was also developed as an eco-friendly filter media to replace traditional plastic filter in order to reduce plastic pollution to water environment. The effluent quality from the system could meet the international standard for agricultural water reuse. The survey data for economic analysis were collected from the 281 households living in the studied area, analyzed by descriptive statistic and Contingent Valuation Method. The results show the fact that household's land use has an inverse relationship while the water source use positively correlates to the value of willingness to pay for wastewater treatment at the statistical significance level of 0.05. The economic analysis of the innovative wastewater treatment system reveals the appropriate wastewater treatment fee at 7 THB per cubic meter of wastewater that is a breakeven point. In addition, the Eco-biofilter/MBR also shows many benefits both of direct and indirect benefits such as water reuse potential, opportunity economic value of treated effluent, and reducing medical expenses. The benefit to cost ratio is equal to 1.04.

Keywords: Eco-biofilter/membrane bioreactor, community wastewater, wastewater treatment and reuse, willingness to pay, contingent valuation method.

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1. Introduction

Water is an important natural resource and essential to humans' lives. Water is used for our daily consumption and occupation, especially in the agricultural sector. Also, water is necessary for crop production which is very important to Thai economy and quality of life since more than 30% of the country's work force has worked in agricultural sector. Moreover, 40% of land use in the country is for agricultural purposes or equivalent to 6.4 million of households [1].

Population growth and the economic expansion are the most important factors that deteriorate natural water quality, which has now become the top priority in environmental problems these days and affected Thai people's health and well-being. This has reflected in the water quality throughout Thailand which ranks at poor to very poor grades. The root cause of the wastewater problem is the discharge of untreated wastewater into natural water sources [2]. Over the past decades, Thailand has encountered a number of water crisis events, such as severe droughts, insufficient water retention of the major reservoirs, water pollution and contamination from big cities, industrial sites, and agricultural areas, together with flash flood from heavy rains. All of the above are creating huge damages to the economy, society, and daily lives of the people and it has become more and more severe as time passes. The problem comes from many factors altogether, from lack of efficient water management, increases of water demand, water consumption behaviors, to global warming [3].

In order to preserve natural resources, the concept of self-restructuring efficiency [4] has often been adopted, especially for the part relating to natural water resources, which has recently become the serious environmental crisis in all big cities. The real causes of water pollution in Thailand are mostly from community wastewater discharges from daily activities. Despite having wastewater treatments in some areas, it is often not efficiently enough since the local government organization lacks of sufficient budget to invest in the construction of wastewater treatment and maintenance fees [5]. The problem of wastewater caused by draining untreated water into the natural water source or not being treated in accordance with the specified standards, law enforcement is not thorough, people rarely participate in the management of wastewater at the source or reduce the discharge, causing the polluter pays principle (PPP) not be implemented [6].

Wastewater treatment with the aim for water recycle is one of the options to preserve natural water in developing countries, especially in suburban areas and rural areas. Decentralized wastewater treatment with Conventional Membrane Bioreactor (MBR) technology is one of the most effective treatment technology for the community [7, 8, 9] as it is a technique that combines original biochemical method and physical method to separate solid substances from liquid substances through the membrane process[10]. The wastewater after treatment will have better quality with less hydraulic retention time, less sludge production, and more efficient nitrification process [11, 12]. Moreover, it requires a small space for installation, low budget, and low maintenance cost in construction [13].

Taesopapong and Ratanatamskul [5] has developed a decentralized wastewater treatment system using the innovative Eco-biofilter/MBR technology with a filter made of baked-clay material as an eco-friendly material instead of plastic filter. The initial survey and study on performance of Eco-biofilter/MBR technology for community wastewater treatment and reuse were done to support efficient water usage campaigns and sustainable preservation. The research is performed at a community in Moo 6 and Moo 7 of Chiang Rak Yai Sub-district, Sam Khok District, Pathum Thani Province, located on the east of Chaophraya river at the point of raw water intake station for Bangkok city's tap water production. The raw water quality has been deteriorated and contaminated from the community wastewater. There are 332 households living in this area who regularly use water from the Chaophraya river. At present, the community wastewater is still untreated and it is discharged directly into the river. The quality of the river water in the study area has been ranked under category 4 of low water quality.

The purpose of this research is to study water consumption behavior, the needs for wastewater treatment and water reuse potential, the factors influencing wastewater treatment technology selection, as well as the willingness to pay for wastewater treatment in the community. Moreover, this research paper aims to focus on the economic analysis in terms of water environment conservation that are not traded in the market (Contingent Valuation Method: CVM), supporting campaigns of using water efficiently and preserving water resources in a sustainable development direction.

2. Description of Eco-biofilter/MBR System for Community Wastewater Recycling and Summary of Performance Evaluation

The developed prototype Eco-biofilter/MBR system at a capacity of 1,000 litre per day has been installed and tested for community wastewater treatment at a community in Moo 6 and Moo 7 of Chiang Rak Yai Sub-district, Sam Khok District, Pathum Thani Province. The system consists of anaerobic filter compartments 1 and 2 as pre-treatment step to remove suspended solid and organic matters for the aerobic membrane compartment as shown in Fig. 1. The ceramic ultrafiltration (UF) membrane with pore size of 0.01 micron is submerged in the aerobic compartment. The Sludge is recirculated from aerobic to anaerobic compartments in order to remove nitrogen due to nitrification and denitrification mechanisms. In this research, a porous baked clay biofilter media is developed as an environmental friendly material in order to reduce plastic pollution from the traditional plastic filter usage and the medias are installed in the anaerobic compartments, prior to the aerobic MBR compartment as shown in Fig. 2. In this study, a waste plastic media made of pol02ystyrene is also installed in another MBR tank as for the performance comparison of porous baked clay filter and plastic filter.

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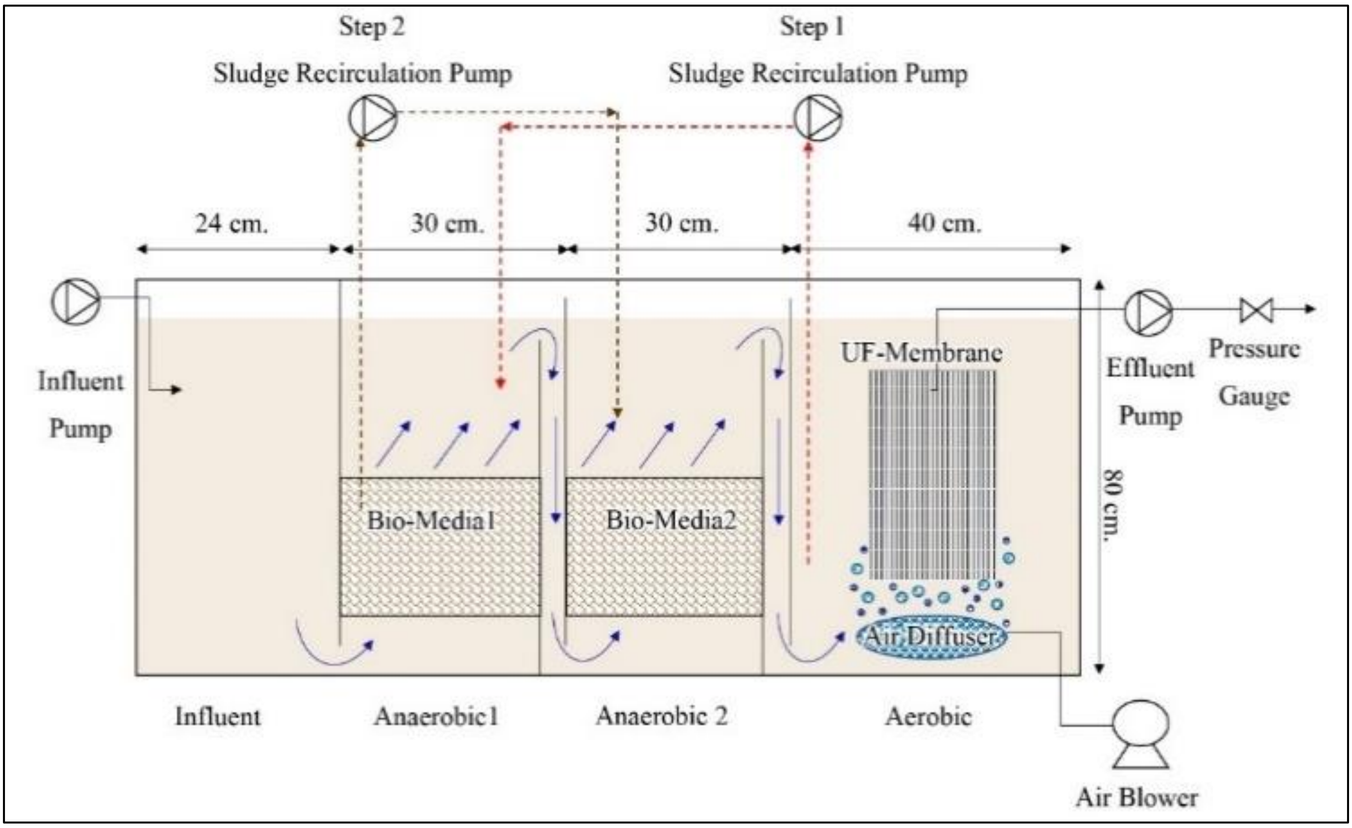

Fig. 1. The prototype Eco-biofilter/Membrane Bioreactor (MBR) with submerged ceramic UF membrane. (Taesopapong and Ratanatamskul, 2020)

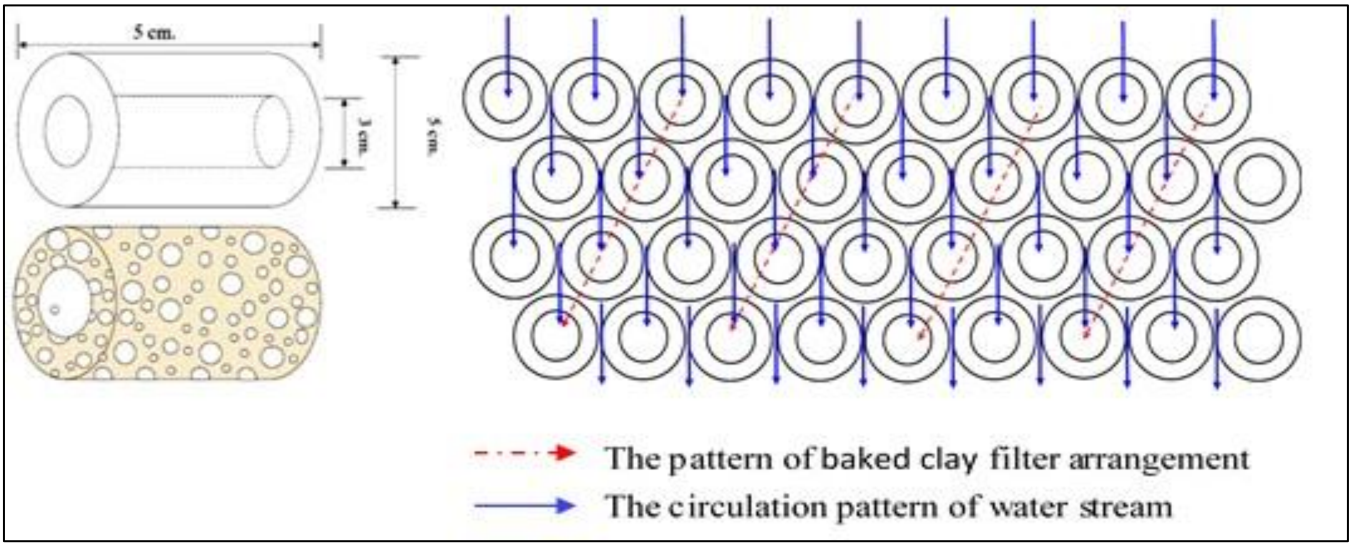

Fig. 2. The developed porous baked-clay filter in the Eco-biofilter MBR system.

The developed porous baked clay biofilter, made from clay, is heated in the oven at temperature 600 degrees Celsius. The material composition of the baked clay biomedia is characterized by X-Ray Fluorescence spectrophotometer (XRF) and can be summarized in Fig. 3. The main compositions of the porous baked clay filter are SiO_2 60.9%, Al_2O_3 25.1%, Fe_2O_3 7.16%, K_2O 2.66% and other element compositions. The media is designed to have the height of 5 centimeters with outer and inner diameters of 5 and 3 centimeters, respectively. The pore size of the baked clay media is 0.02 micron, whereas the pore volume of the media is 14.9%.

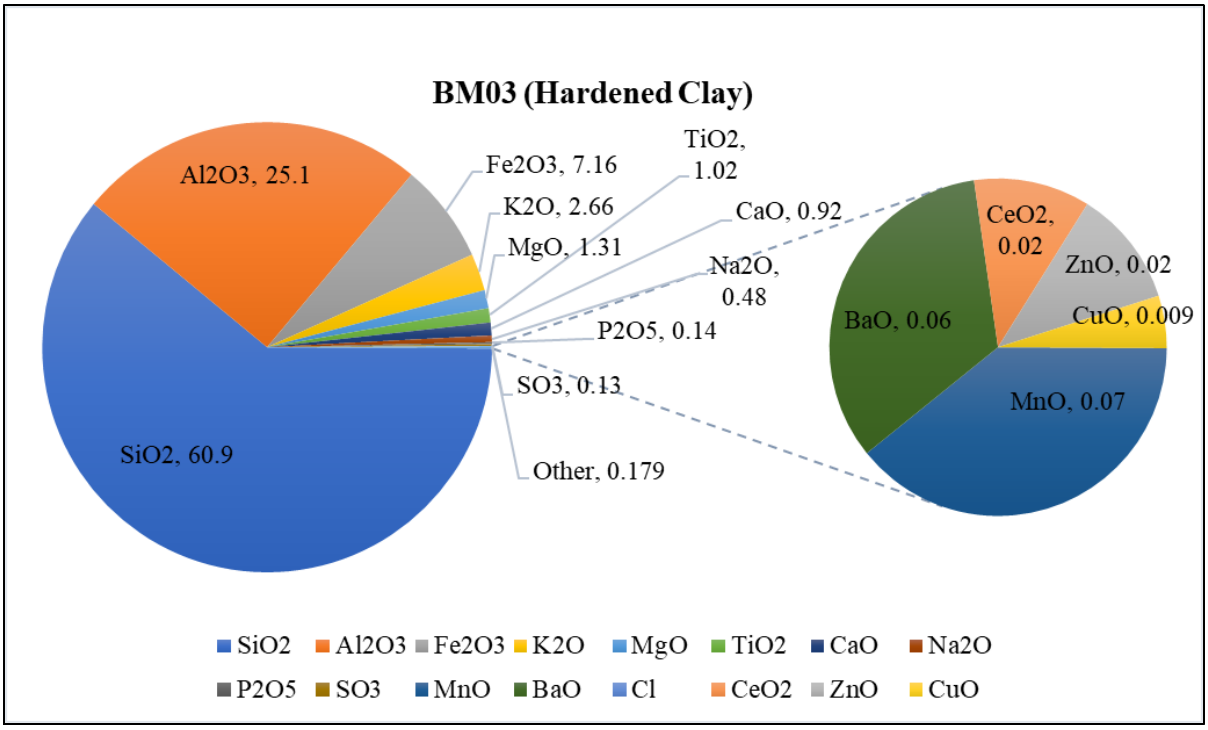

Fig. 3. The composition of a porous baked-clay filter, developed to replace plastic filter in this study.

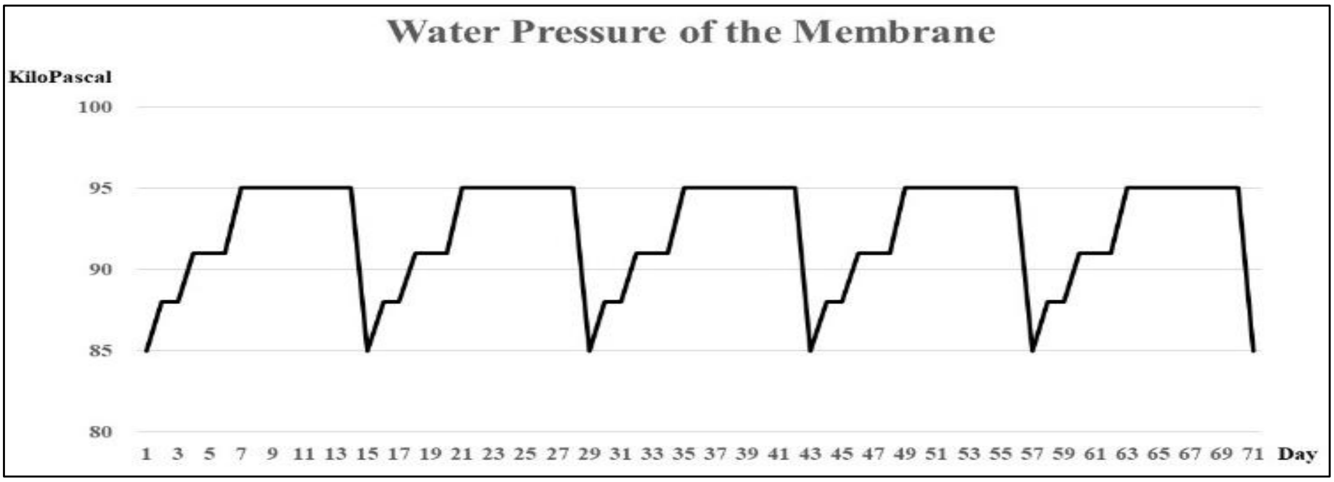

Fig. 4. The operating transmembrane pressure of ceramic UF membrane in the Eco-biofilter MBR system operation.

The ceramic UF membrane is controlled to have a filtration rate in the range of 300–360 l/m²-d. The membrane is taken out for cleaning when the transmembrane pressure is raised to 95 KPa as shown in Fig. 4. From Fig. 5, the result shows that the Eco-biofilter/MBR system is an efficient technology capable of maintaining neutral pH value, reducing Biochemical Oxygen Demand (BOD), Total Suspended Solid (TSS) to comply with the domestic effluent standard while creating new bacteria cells to decompose large organic substances. As a result, the pH value after the treatment becomes more neutral, facilitating new bacteria to decomposes organic substances effectively and reducing suspended solid, the cause of turbidity of the water, making it clearer at the end. The Eco biofilter technology uses porous baked clay filter to capture suspended solid particles in wastewater and help decomposed these organic substances inside the anaerobic compartment before letting them flow to the aerobic compartment.

Since the community wastewater in this study is very diluted and has low BOD concentration, the synthetic wastewater was prepared and added to the incoming wastewater in order to raise the BOD concentration in order to know the potential of organic removal by the Eco biofilter/MBR system. In the initial period (Day 1- Day 15), high sucrose solution with BOD concentration of 2,500-3,700 mg/L and urea, CH_4N_2O 200 mg/L was also added to the incoming wastewater. The BOD concentration was increased up to 3,700 mg/L at Day 15 to know any shock loading problem to the system.

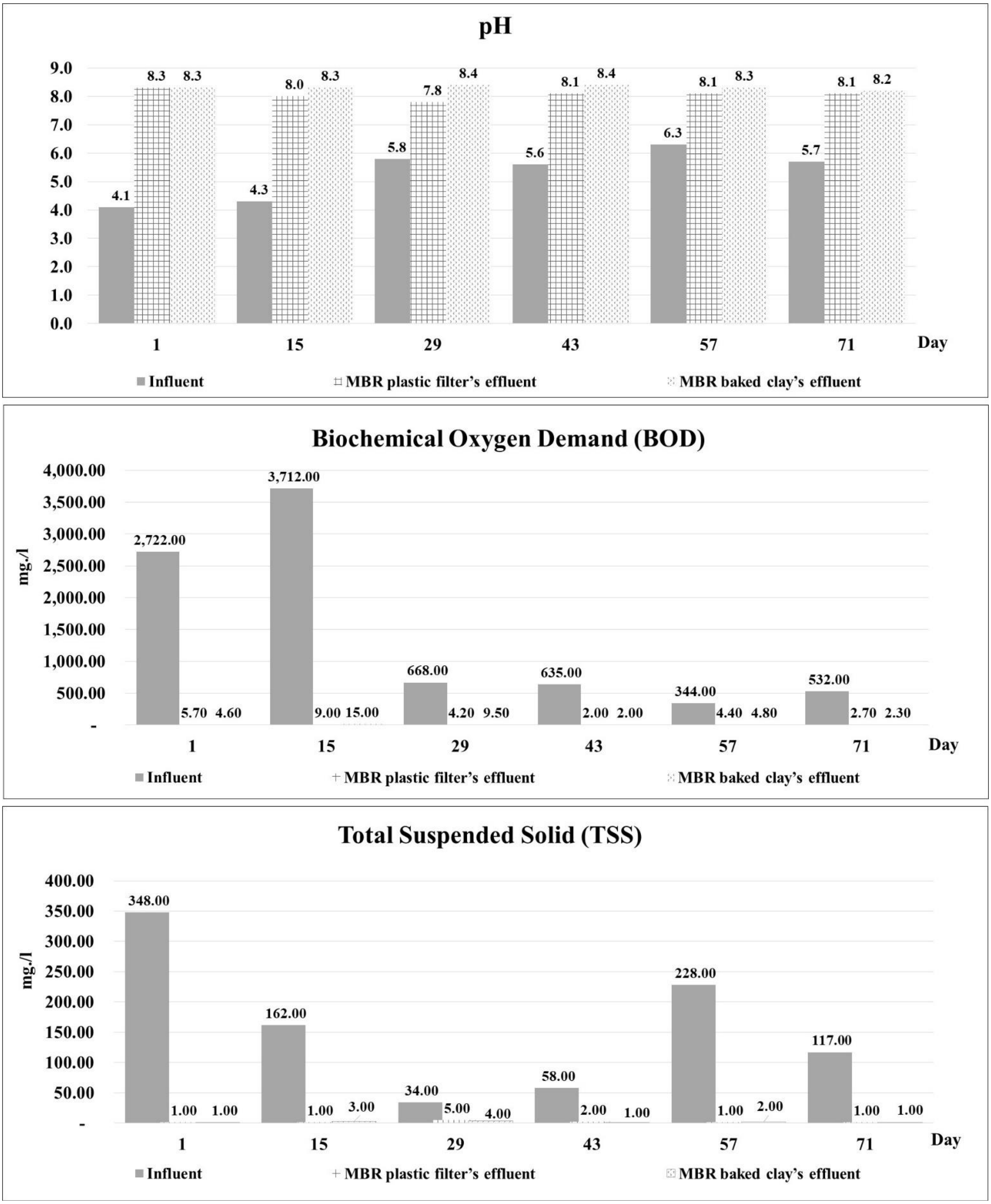

Fig. 5. The performance comparison of the Ecobiofilter/MBR and the plastic filter/MBR systems.

Summary of system performance evaluation

From Fig.5, the effluent quality after both treatment processes of Eco-biofilter/MBR and plastic biofilter/MBR systems can comply with domestic effluent standard (BOD less than 20 mg/L; SS less than 30 mg/L; pH 5.5–9.0). Therefore, it is indicated that the developed porous baked clay filter can function effectively and has high potential to replace the traditional plastic filter in order to minimize plastic pollution problem to water environment. Moreover, the overall treated effluent quality by Eco biofilter/MBR technology using porous baked-clay filters yields the pH, BOD, TSS and FCB values satisfying the water reuse standard specified by the Environmental Protection Agency of the United States [14] for reuse in agriculture.

Table 2 shows that the effluent quality that has been purified through Eco biofilter/MBR technology has pH, BOD, TSS and FCB in line with the water quality standard specified by The United States Environmental Protection Agency for reuse in agriculture on food crops, processed food crops and non-food crop. Moreover, nitrogen and phosphorus in the treated effluent can be utilized as fertilizer for the growth of crop as well.

Table 2. Comparison of purified water quality obtained from wastewater treatment with Eco biofilter/MBR technology against the international water quality standard defined by The United States Environmental Protection Agency.

Parameters	Effluent Quality		Wastewater Reuse Criteria		
	Plastic Filter	Baked Clay Filters	Food Crops[1]	Processed Food Crops[2]	Non-Food Crop[3]
pH	8.1±0.16	8.3±0.08	6 – 9	6 - 9	6 – 9
BOD (mg./l)	4.67±2.50	6.37±5.01	<10	<30	<30
TSS (mg./l)	1.83±1.60	2.00±1.27	N/A	≤30	≤30
FCB (MPN/100 ml)	<1.80	<1.80	No Detect able	≤200	≤200

Note: [1] Food Crops: The use of reclaimed water for surface or spray irrigation of food crops which are intended for human consumption, consumed raw.
[2] Processed Food Crops: The use of reclaimed water for surface irrigation of food crops which are intended for human consumption, commercially Processed.
[3] Non-Food Crops: The use of reclaimed water for irrigation of crops which are not consumed by humans, including fodder, fiber, and seed crop, or to irrigation pasture land, commercial nurseries, and sod farms.

3. Research Methodology for Economic Analysis of the Eco-biofilter/MBR System

3.1. Collecting Data

In this research, the data survey on water source consumption behaviors, wastewater treatment behaviors, the needs for wastewater treatment, factors on technology selection for wastewater treatment, and the willingness to pay for wastewater treatment in the community were performed. The data were collected from the households living in the area of Moo 6 and Moo 7, Chiang Rak Yai Sub-dictrict, Sam Khok District, Pathum Thani Province. The data comprise 144 households from Moo 6, and 188 households from Moo 7, or a total of 332 households (data from Household Registra Office on October 25, 2018). The researchers determine the sample group of at least 182 households, calculated by Taro Yamane Formula [15] at 5% discrepancy level, as follow:

$$n = \frac{N}{1 + N(e)^2} = \frac{332}{1 + 332(0.05)^2} = 181.42$$

Where, N is numbers of population
n is size of the sample group
e is level of acceptable discrepancies

The data collection was conducted through use of questionnaires to collect data based on descriptive statistics, to describe and elaborate the characteristics of the data. The qualitative data were computed for frequency, mode, and percentage, while the quantitative data were computed for mean value and standard deviation. In order to analyze the willingness to pay for wastewater treatment in the community of the sample group from this hypothesis model, or to analyze the correlations between the relevant factors and the willingness to pay for wastewater treatment in the community, the researchers divided the wastewater treatment fee into five different price levels; 4, 6, 8, 10 and 12 THB for one cubic meters of wastewater (equal to 1,000 liters) in order to know the optimal treatment fee that can be applied for sustainable wastewater management.

3.2. Economic Analysis of Natural Resources and Environment That Are Not Traded in the Market (Contingent Valuation Method: CVM)

The economic valuation of natural resources and environment that are not traded in the market makes use of direct interviews which evaluate the willingness to pay (WTP) in the hypothetical market. The interviews or questionnaires are given to related parties, who are responsible for making decisions on cost budgeting to avoid risks or to gain additional benefits. The willingness to pay varies from person to person, depending on one's satisfaction and one's budgets [16]. Prior to the interview, the interviewers need to inform the interviewees about risks and benefits regarding values of changes in actual environment or in the hypothetical markets [17].

This research is to conduct economic valuation of natural resources and environment that are not traded in market with use of mean willingness to pay (Mean WTP). The research uses contingent valuation method (CVM) by employing closed-ended questions to indicate a single value (Single Bounded CVM).

The variables used to derive the correlations with the value of willingness to pay for wastewater treatment include household income, number of household members, distance from home and water sources, the period of residence, land use, natural water use, awareness of wastewater treatment of household (shown in Table 3).

Table 3. Definitions of model variables.

Variables	Definitions	Values of Variables	Types of Variables
WTP	The value of willingness to pay for wastewater at five price levels; 4 HB, 6 THB, 8 THB,10 THB and 12 THB per 1 cubic meter of water per month (quantitative variable)	THB	Dependent variable
Income	Household income per month (dummy variable)	0 = ≤30,000 THB 1 = >30,000 THB	Independent variable
Member	Household member (quantitative variable)	persons	Independent variable
Location	Distance from home to water source (dummy variable)	0 = >100 meters 1 = ≤100 meters	Independent variable
Period	Period of residence (dummy variable)	0 = ≤10 years 1 = >10 years	Independent variable
Land	Land use of household (dummy variable)	0 = housing 1 = others	Independent variable
Use	Use of water source (dummy variable)	0 = No 1 = Yes	Independent variable
Awareness	Awareness of wastewater treatment of household (dummy variable)	0 = not important 1 = Important	Independent variable

The willingness to pay: (WTP) is a concept in microeconomics describing consumer's willingness to pay for goods and services. It models consumer behavior under the assumption that each individual consumer is rational i.e. a consumer enjoys maximum utility of goods and services that he pays for under given limited budget. This research proposes a model employing the consumption of utility principle to study the quality of living of the households in the community using decentralized wastewater treatment technology called Eco-biofilter/MBR system to remove contaminants from water sources in the local area. The relationship between the willingness individual household will pay to treat wastewater in the community and relevant variables can be described in equation (1) as following:

$$WTP = \alpha + \beta_1 Income_i + \beta_2 Member_i + \beta_3 Location_i + \beta_4 Period_i + \beta_5 Land_i + \beta_6 Use_i + \beta_7 Awareness_i + \varepsilon_i \qquad (1)$$

Where, WTP is the value of willingness to pay for wastewater treatment in the community

α is a constant

β_1–β_7 are the coefficients of the independent variables

ε is an error term

In this research also conducts cost-benefit analysis to be government decision-making tools to allocate resources in the best possible way for better social welfare projects or policies by considering the benefits and costs of society.

4. Results

4.1. General Information of Households Living in the Community

The researchers collected data from 281 sample of households living in Moo 6 and Moo 7 area of Chiang Rak Yai, Sam Khok district, Pathum Thani province. Most households have family members of no more than 5 people. This is accounted for 92.17% of the sample. In addition, most households have monthly income of not over 30,000 THB, 85.05% of the total sample. Most households live near local water sources by no farther than 100 meters, 72.24% of the sample. The family members of most households have resided for more than 10 years which, accounted for 80.78% and 86.83% of the sample uses land as housing.

4.2. Water Consumption Behavior

According to the sample, 13.17% of households use water from local rivers and canals while the majority of households use municipal water service with average monthly water bill per household of 300 THB. All in most questionnaire respondents use water from local rivers and canals very few times. The three most frequent activities that the respondents use water from local rivers include bathing, house cleaning and laundry (with mean values of 1.60, 1.57, and 1.53 and standard deviations of 0.869, 0.888 and 0.954 respectively). Household activities causing wastewater in the community include bathing and laundry which are accounted for 26.02% and 24.43%, respectively. Even though most households in this sample use municipal water service as the main source of water use a good portion of 13.17% of the sample households especially those who live near the rivers use water from the local rivers and canals for their daily activities such as bathing, house cleaning and laundry. The most common wastewater problems found in the community are garbage and weed floating on water and dirty black water, accounted for 39.88% and 37.57%, respectively.

4.3. Wastewater Treatment Behavior

According to the survey, the most common form of wastewater releases caused by the households is wastewater released from home to ground (mean = 2.5, standard deviation = 1.039) followed by wastewater released to sewers, wastewater released to rivers/canals and others. (mean = 1.70, 1.51 and 1.01 with corresponding standard deviations = 1.241, 0.93 and 0.84 respectively). Above all, 71.89% of the sample households treat wastewater before releasing it out. The most common tools are food residual filters (mean = 2.11, standard deviation = 1.388) followed by grease trap filters, septic tanks and wastewater tanks (means = 1.39, 1.18 and 1.14, standard deviations = 0.987, 0.636 and 0.612, respectively). In addition, the survey reveals that 92.88%

of the sample households believe it is very important to treat wastewater before releasing it out because wastewater treatment can make water clean. The majority of the sample household receive news and information regarding wastewater treatment from television and the local community broadcast at 42.09% and 24.43%, respectively. Nonetheless the sample households barely reuse water (mean = 1.4, standard deviation = 0.725).

4.4. Needs of Wastewater Treatment

According to Table 4, the top 3 most essential needs for wastewater treatment include building awareness on water conservation, information on wastewater treatment and engagement of local residents on wastewater treatment (means = 3.03, 2.93 and 2.93, standard deviations = 1.083, 1.017 and 1.123, respectively). The least essential need is wastewater reuse (mean = 2.47, standard deviation = 1.025).

Table 4. Needs of wastewater treatment of the sample group (n = 281).

Needs	Mean	S.D.	Degree of Needs
1. Building awareness on water conservation	3.03	1.083	medium
2. Information on wastewater treatment	2.93	1.017	medium
3. Engagement of local residents on wastewater treatment	2.93	1.123	medium
4. Knowledge on wastewater treatment	2.92	0.932	medium
5. Efficient wastewater treatment system	2.88	1.129	medium
6. Knowledgeable personnel	2.80	1.206	medium
7. Systematic wastewater treatment	2.79	1.135	medium
8. Wastewater reuse	2.47	1.025	medium
Total	2.84	1.081	medium

4.5. Influential Factors to Wastewater Treatment Technology Selection

According to Table 5, the five most influential factors to wastewater treatment technology selection include ease of use of the treatment technology, ease of maintenance of the treatment technology, efficiency of the treatment technology, cost of the treatment technology and ease of knowledge sharing of the treatment technology (means = 3.18, 3.16, 3.15, 3.14 and 3.08, standard deviations = 1.105, 1.028, 0.968, 1.135 and 1.008, respectively).

Table 5. Influential factors to wastewater treatment technology selection of the sample group (n = 281).

Needs	Mean	S.D.	Degree of Needs
1. Ease of use of the treatment technology	3.18	1.105	medium
2. Ease of maintenance of the treatment technology	3.16	1.028	medium
3. Efficiency of the treatment technology	3.15	0.968	medium
4. Cost of the treatment technology	3.14	1.135	medium
5. Ease of knowledge sharing of the treatment technology	3.08	1.008	medium
6. Degree of negative impacts from wastewater problems	3.05	1.048	medium
7. Importance of wastewater treatment	3.01	0.969	medium
8. The treatment technology with minimal installation area	2.90	0.951	medium
9. Energy efficiency of the treatment technology	2.86	0.950	medium
10. The treatment system made of environmental friendly components	2.80	0.841	medium
11. Water quality after the treatment	2.76	0.964	medium

The least influential factor is the water quality after the treatment (mean = 2.76, standard deviation = 0.964). In addition 72.60% of the sample group is interested in more improved treatment technology.

4.6. The Willingness to Pay for Wastewater Treatment in Local Community

The majority of the sample (53.02%) do not agree to pay for wastewater treatment service because they already pay tax to the government. They believe that the treatment expense should be paid by the relevant government agencies and not by the local community. Nonetheless, based on a hypothetical case study which estimates the willingness to pay for wastewater treatment by offering five price levels namely 4, 6, 8, 10 and 12 THB for 1 cubic meter (1,000 liters) of wastewater per month, a large number of respondents are willing to pay for wastewater treatment by 4 THB. This group is accounted for 22.42%. Other groups are willing to pay 6 THB, 8 THB, 10 THB and 12 THB with the corresponding portions of 16.37%, 6.05%, 1.78% and 0.36%, respectively.

When considering the characteristics of the samples classified by willingness to pay which found interesting issues can be shown in Table 6.

Table 6. Characteristics of the samples classified by willingness to pay (n = 281).

Characteristics	**Group of not agree to pay (n=149)**	**Group of willing to pay (n=132)**
Age		
- 21-30 years old	2.68%	7.58%
- 31-40 years old	10.74%	15.15%
- 41-50 years old	18.12%	15.15%
- 51-60 years old	35.57%	26.52%
- Over 60 years old	32.89%	35.60%
Total	100.00%	100.00%
Income (THB per month)	62.42%	63.64%
- Not over 15,000	24.16%	19.70%
- 15,001-30,000	13.42%	16.66%
- More than 30,000		
Total	100.00%	100.00%
household Member		
- Not over 5	89.55%	83.33%
- More than 5	8.05%	16.67%
Total	100.00%	100.00%
Location of house from natural water sources		
- Near	36.24%	45.45%
- No farther than 100 meters	34.23%	28.79%
- Farther than 100 meters	29.53%	25.76%
Total	100.00%	100.00%
Residence period (year)		
- Not over 10	16.78%	21.97%
- 11 – 20	28.86%	4.55%
- More than 20	54.36%	73.48%
Total	100.00%	100.00%
Land use		
- Residential only	81.88%	92.42%
- Commercial	14.76%	6.06%
- Agriculture	3.36%	0.76%
- Dormitory/Hotel	-	0.76%
Total	100.00%	100.00%
The use of natural water sources		
- Yes	1.34%	26.52%
- No	98.66%	73.48%
Total	100.00%	100.00%

Table 6. Characteristics of the samples classified by willingness to pay (n = 281) (continued).

Characteristics	**Group of not agree to pay (n=149)**	**Group of willing to pay (n=132)**
Awareness of wastewater treatment before discharging		
Yes	94.63%	90.91%
No	5.37%	9.09%
Total	100.00%	100.00%

According to Table 6, the characteristics of the samples classified by willingness to pay fee for wastewater treatment which found interesting issues as follows: (1) major respondents who are between 41–60 years old will be less willing to pay compared with the other age since they are a period of age with expenses related to the assets and education of children, therefore pay less attention to other expenses (2) respondents who have income between 15,001-30,000 THB per month will be less willing to pay as they pay importance to stability in life, such as buying a house, buying a car, etc. (3) respondents who have number of household member more than 5 will be more willing to pay since more household member will need more water use (4) respondents who have houses near natural water sources are more willing to pay than those with houses far away from natural water sources due to more environmental benefits from natural water sources (5) respondents who live in the community between 11-20 years will be less willing to pay compared with another groups (6) respondents with land use for residential purpose only will be more willing to pay compared with those who use the land for other purposes (7) respondents who uses natural water sources are more willing to pay the fee for wastewater treatment since they have utilized natural water sources and (8) respondents who have awareness of wastewater treatment before discharging are less willing to pay for wastewater treatment fee since they thought that they already pay the income tax, therefore there is no need to pay additional wastewater treatment fees.

The results show that the samples who are willing to pay for community wastewater treatment are respondents with sufficient and high income, large household member, houses near natural water sources, resident period in the community for a long time. While the respondents who have awareness of wastewater treatment before discharging are less willing to pay the fee for wastewater treatment. However, providing information and environmental education program to create conscious mind of environmental conservation as well as raising awareness about the environmental benefits that people in the community will receive from having an effective wastewater treatment system is one way to stimulate participation and increase the willingness to pay.

4.7. Economic Valuation of Natural Resources and Environment that are not Traded in the Market (Contingent Valuation Method: CVM)

In this section, we study the relationship between various independent variables and the willingness to pay for wastewater treatment in local community of the sample group. The equation takes into account household monthly income, number of household members, distance from home to water sources, period of residence, land use, water resource use, and awareness of wastewater treatment of household. However, age is not tested in correlation to the willingness to pay, since most respondents are older than 50 years (about 65%). The results are shown in Table 7.

According to Table 7, the analysis of the willingness to pay for wastewater treatment in local community reveals that land use and water source use has a statistical significance of 0.05 to the willingness to pay for wastewater treatment. The land use factor inversely correlates to the willing to pay for wastewater treatment. Another words those households who use land for housing are more willing to pay for wastewater treatment than those who use land for other purposes such as stores, apartment, agriculture etc.

Table 7. Results of the willingness to pay for wastewater treatment of the samples.

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant (α)	3.398	0.739		4.597	0.000
Income	0.296	0.491	0.036	0.604	0.547
Member	-0.011	0.096	-0.007	-0.109	0.913
Location	0.005	0.352	0.001	0.014	0.989
Period	0.109	0.431	0.015	0.252	0.801
Land	-1.107	0.503	-0.127	-2.201	0.029
Use	3.016	0.500	0.346	6.030	0.000
Awareness	-1.197	0.646	-0.104	-1.854	0.065

This is due to the fact that 86.83%of the households in this sample group use land for housing. They believe that more spending on wastewater treatment will improve the water quality in the community, improve the scenery of the neighborhood and promote better life quality of the residents in the community. The water source use factor positively correlates to the willing to pay for wastewater treatment. Those households who use natural water sources are more willing to pay for wastewater treatment. This is due to the fact that most households in the sample group expect that more wastewater treatment spending will significantly improve the river water quality. The treated effluent will have better quality for further water reuse in their daily activities. Monthly household income, number of family members, location or distance from home to water source, period of residence and awareness of wastewater treatment do not correlate with the willingness to pay for wastewater treatment at the statistical significance level of 0.05.

With data obtained from Table 6, we now can derive an equation describing the value of willingness to pay for wastewater treatment in the community of the sample group as shown in equation (1) below.

$$WTP = 3.398 + 0.296Income_i - 0.011Member_i + 0.005Location_i + 0.109Period_i - 1.107Land_i + 3.016Use_i - 1.197Awareness_i + \varepsilon_i$$

The average value of the willingness to pay for wastewater treatment in the community of the sample group of 281 households is equal to 2.636 THB per household per month for 1 cubic meter of wastewater. From the survey, on average consumption of water is 22 cubic meter per household per month. Therefore, the total value of willingness to pay for wastewater treatment in the community of the sample group totally 332 households is 2.636 x 22 x 332 = 19,253.344 THB per month or 231,040.128 THB per year. But if considering the willingness to pay at 4 THB per household per month for 1 cubic meter of wastewater, which is the base mode for consideration, the total value of willingness to pay for wastewater treatment in the community of the sample group totally 332 households will be 4 x 22 x 332 = 29,216 THB per month or 350,592 THB per year.

The cost evaluation of the application of Eco-biofilter/MBR system for treatment of community wastewater at 300 m^3/day (from 332 households) was performed based on these assumptions/considerations: (1) local government organization invests in the capital cost of system development, in which households in the community participate in the payment of operating and maintenance (O&M) cost; (2) The O&M cost estimation was based on the pilot plant study that comprised of electricity cost and chemical cost per unit of treated wastewater flowrate, and system maintenance cost was estimated at 2% of system depreciation cost; (3) The ceramic membrane lifetime was longer than 20 years; (4) The time horizons for this project evaluation was 20 years (see Table 8).

Table 8. Analysis of operating and maintenance (O&M) cost for application of the innovative Eco-biofilter/MBR system in treating community wastewater at 300 m^3/day.

Cost Category	Details	Amount (THB/year)
1. Electricity utility	- The capacity to treat 300 cubic meters of wastewater per day - Electricity use equals to 5 THB per treated wastewater flowrate, accounted for electricity charge equal to 45,000 THB per month	540,000
2. Chemical substance	- Cost of chemical cleaning agent equals to 2,500 THB per month	30,000
3. System maintenance	- Maintenance cost 20,000 per month	240,000
4. Depreciation	- Cost equal to 20,000,000 THB - Useful life equal to 20 years - There is no salvage value - Calculated with straight – line method	1,000,000
Total		1,810,000

According to Tables 8 and 9, the total O&M cost of Eco-biofilter/MBR system for the treatment of community wastewater from 300 households equals to 1,810,000 THB per year. While the total benefits in terms of average willingness to pay (WTP) as well as the treatment fee were considered at various scenarios of 4, 5, 6, 7, 8, 10, and 12 THB per cubic meter of wastewater, the obtained benefits were 1,403,038, 1,550,350, 1,658,350, 1,766,350, 1,874,350, 1,982,350, 2,198,350, and 2,414,350 THB per year, respectively. Furthermore, it shows the benefit to cost ratio equal to 0.78, 0.86, 0.92, 0.98, 1.04, 1.10, 1.21, and 1.33, respectively. It can be shown that collecting fees for wastewater treatment at 7 THB per cubic meter of wastewater is a breakeven point. Thus, it can add positive economic value to water environment management. Even more worth when realizing the revenue from tourism resulting from beautiful scenery and value added of agricultural products both of quantity and quality resulting from better quality of water. Moreover, the current changing environment has caused water shortages both in quantity and quality deterioration. Therefore, the Provincial Waterworks Authority has to use the budget to continually invest in the development and maintenance of raw water sources [18]. Water treated with the innovative Eco-biofilter/MBR system is another way to provide alternative raw water sources and reduce those spending since it has the potential to treat and recycle treated wastewater for water circulation and reuse to compensate the water demand for the community. Moreover, it also uses environmental friendly materials by reducing the use of plastic, which reduces the cost of plastic waste disposal and pollution from plastic waste for a better quality of life which cannot be invaluable.

Table 9. Scenario of the revenues obtained from the wastewater collection fee at WTP level and different wastewater treatment fees (set by local government).

Benefits	Details	Amount (THB/year)							
		Average WTP	**Treatment Fee 4 THB**	**Treatment Fee 5 THB**	**Treatment Fee 6 THB**	**Treatment Fee 7 THB**	**Treatment Fee 8 THB**	**Treatment Fee 10 THB**	**Treatment Fee 12 THB**
Direct benefit - WTP	- Average WTP is 2.636 THB per household per month for 1 cubic meter of wastewater - Fee of treated effluent of Pollution Control Department is 4 – 12 THB per household per month for 1 cubic meter of wastewater - The capacity to treat 300 cubic meters of wastewater per day	284,688	432,000	540,000	648,000	756,000	864,000	1,080,000	1,296,000
- Opportunity value of treated effluent	- Price of treated effluent is 0.3 USD per 1 cubic meter [19] - The capacity to treat 300 cubic meters of wastewater per day	1,018,350	1,018,350	1,018,350	1,018,350	1,018,350	1,018,350	1,018,350	1,018,350
Indirect benefit - Reduced medical expenses	- Medical treatment expense for diseases caused by water pollution (estimated by community health center in studied area)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Total		1,403,038	1,550,350	1,658,350	1,766,350	1,874,350	1,982,350	2,198,350	2,414,350
The benefit to cost ratio		0.78	0.86	0.92	0.98	1.04	1.10	1.21	1.33

5. Discussion and Conclusion

The decentralized wastewater treatment system with the innovative Eco-biofilter/MBR technology can be an efficient wastewater treatment system for communities in Thailand. The treatment process can reduce organic contaminants, oil and grease, solid form solute, nitrogen, protein and fecal coliform bacteria very effectively. The treated effluent quality passes the water quality standard specified by the Environmental Protection Agency of the United States that can be reused for agriculture. The wastewater treatment system benefits the Thai society in terms of reducing pollution and contamination in water sources, promoting sustainable water conservation through improving wastewater quality and making it reusable. In addition, it helps to solve water shortage problems for Thai farmers who are the backbone of the nation.

The economic evaluation in this study employs mean WTP method with singled bounded CVM and uses the SPSS program to perform data analysis to derive the relationship between various independent variables and the value of willingness to pay for wastewater treatment in the community. The analysis of the value of willingness to pay for wastewater treatment in the community reveals that the fee of wastewater treatment at 7 THB per cubic meter of wastewater is a breakeven point by causing totally benefits for 1,874,350 THB per year, while the total cost equal to 1,810,000 THB per year, calculated B/C ratio equal to 1.04. It is possible that the local municipal is able to collect the wastewater treatment service charge from the sample households at the breakeven rate due to the fact that these households are aware of the essence of wastewater treatment and they expect that the decentralized wastewater treatment with Eco-biofilter/ MBR technology will benefit the community through pollution reduction, beautiful water scenery, better quality of living and wastewater reuse etc.

However, in the initial of the operation, the local municipality might charge the fee for treating wastewater at the rate of half of the break-even point is 4 THB per cubic meter of wastewater, with the local municipality issuing the other half. Moreover, they should educate and publicize information to stimulate awareness of the importance of wastewater remediation in the community, including the benefits that those who live in the community will receive to encourage households to be more willing to pay for wastewater treatment such as environmental education, training for community participation in environmental conservation, promoting environmental conservation activities, etc. It also helps households who do not realize the need to pay these fees have a feeling to participate in paying this fee, too. Moreover, reducing expenses or efficiency improvement of the wastewater treatment system in long run will also increase more confidence [20]. There should be further researches on system design and development to reduce the operating and maintenance cost in long run, leading to sustainable water conservation.

Therefore, this research can recommend an efficient community wastewater treatment system for the wastewater management policy planning through cost analysis and benefit projection since the decentralized wastewater treatment using the innovative Eco-biofilter/MBR technology t can significantly reduce water pollution load in order to protect the water supply source for drinking water as well as the system can make the treated effluent recyclable for agriculture use purposes. Furthermore, Eco-biofilter/MBR shows many benefits both of direct and indirect benefits such as water reuse potential, opportunity economic value of treated effluent, and reducing medical expenses.

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