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A Bench Scale Study on Polluted Canal Water Purification in Comparison between with and without Addition of Fermented Products

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Abstract

This study aimed to investigate the possibility of using five types of fermented product (FP) to improve the removal efficiency of basic pollutants (under aerobic condition via strong agitation), i.e., non-filtered COD_T, BOD_T and SS presenting in two polluted canals in Bangkok area, namely, San Saeb and Kaja canals. The results were compared with the 'Control' experiment, which was without the addition of any fermented products (FPs). Obviously, it was found that the addition of FPs (containing high VFA) increased the COD_T concentration of the raw polluted water from 52 to the range of 87 – 107 mg/L. However, there was no clear-cut conclusion on the benefit of the FP addition in this study. Also, it was apparent that all five designated FPs gave similar treatment results. The only advantage of the FP supplement was to increase the MLSS or bacteria mass in less time, which is good for a startup process. However, bacterial mass (MLSS) can be enhanced through an ordinary startup without necessity of FP addition if there is no any particular problem. In conclusion, BOD and COD removals in the reactors with FP addition were not significantly different from the 'Controls', which eventually determined that EM and FPs addition cannot effectively treat polluted water.

Keywords : Effective Microorganism (EM); fermented products (FPs); polluted water; canal water; PNSB

Introduction

According to the severe flood situation in Thailand during the year 2011 that covering large area in central part of Thailand, polluted floodwater became a national issue at that moment. Enormous amounts of floodwater could not be easily dried out and subsequently became stagnant. Dark color, debris and strong odor of stagnant water caused a nuisance to residences among the flood. Without sufficient scientific evidences, fermented products (FPs) were claimed to help relief polluted water problems. Some government expenditures were even planned for FP application with this purpose of polluted water treatment.

Fermented Products (FPs) here refer to the products, both chemical and biological, obtained from the fermentation of glucose and lactose in plants, fruits or meats with the assistant of molasses (or other sugar-containing substances). The fermentation results in different readily degradable volatile fatty acids (VFAs) such as acetic and propionic acids as well as anaerobic lactic acid bacteria (LAB), yeast and actinomyces. Whereas photosynthetic bacteria (PB) such as purple non-sulfur bacteria (PNSB) are exaggerated by some to be abundant in these

FPs [1]. The PNSB under anaerobic condition are claimed to be able to, through the photosynthesis process, reduce bad odor by oxidizing sulfide to element sulfur, as shown in Eq. 1.

$$CO_2 + H_2S \rightarrow (CH_2O) + H_2O + S \quad (1)$$

EM or Effective Microorganism is the trade name of a main FP available in some parts of the world [2]. It was firstly developed by Teruo Higa in 1970s. Several EM-like products claimed during the flood situation (year 2011) had usually been made by composting food, vegetable or fruit wastes and natural microbial inoculums from the fertile soil from various sources. These are mixed with molasses to form EM liquid, while some are mixed with appropriate ratio of rice chaff, bran, sand, and mold to compress the size of a tennis ball to form EM ball. It has been reported that the solution contained over 80 microbial species from 10 genera, including lactic acid bacteria (LAB), phototrophic bacteria, and yeast [3, 4]. Some EM applications were suggested include agricultural activities, household cleaning, probiotic for pets and animals, wastewater treatment and purification, and waste management [5-11].

For agricultural activities, EM has been claimed to be used as a soil conditioner [5], increasing plant health, yield and nutrition. For environmental management, EM has been used in some communities for waste or wastewater treatment [12-13], and also used for treating sludge from wastewater treatment plant [14]. Some researchers using EM in wastewater treatment plant claimed that EM could reduce odor, COD, BOD and suspended solids (SS) [3, 15-16]. However, these researchers mostly conducted their experiments without the Control system, thus**, it has been unclear that the COD, BOD and SS reduction was achieved due to the self-purification of the river/canal or the capability of the EM**.

Therefore, this study aimed to scientifically evaluate the possibility of using five different FPs to improve water purification under aerobic condition. Two canals from different locations in Bangkok area were designated to for comparison. In addition, the Control system (without addition of any FPs) were identically setup in order to obtain self-purification characteristics of polluted canals.

Methodology

Polluted water

Due to this study was setup after the severe flood in 2011, polluted water from the flood was not existed anymore. Hence, the authors chose polluted canals in Bangkok area to imitate polluted floodwater. In this article, polluted waters were taken from two canals, i.e., San Saeb and Kaja canals, Bangkok, Thailand with enough amount for all experiments in this study. The average characteristics of two polluted waters were shown in Table 1.

Table 1 Characteristics of polluted waters

Parameters	**San Saeb canal**	**Kaja canal**
Temp (^oC)	30.5	31.5
pH	7.31	7.21
DO (mg/L)	1.67	2.07
Turbidity (NTU)	0.73	1.93
BOD (mg/L)	23.2	48.3
COD (mg/L)	72.3	98.9
SS (mg/L)	38	24

Fermented Product (FP)

Five different types of Fermented Products (FPs) used in this study were commercially sold in the market. These five FPs were sampled and determined for their existing expected heterotrophs, results of which were shown in Table 2 [17]. The application ratios of FPs to water for general purposes recommended by their suppliers were mostly 1:10,000. However, the ratios of FP to polluted water applied in this study (Table 3) were selected from the optimum ratios resulted from previous work [18].

Table 2 Amount of heterotroph microorganisms in each fermented products [17]

Type of FPs	Total bacteria as SPC (CFU/ml)	Lactic acid bacteria (CFU/ml)	Purple non-sulfur bacteria(CFU/ml)
FP 1*	201,000±1,732	8,733±58	127±4.6
FP 2*	34,667±577	3,033±153	101±7.8
FP 3**	56,333±1,528	6,067±208	600±43.6
FP 4**	54,000±1,732	290±10	176±1.0
FP 5*	1,340,000±10,000	187,000±10,000	156±3.5

*Company's product
**Produced by local people; FP 4 was produced from fermented mushroom

Table 3 Ratios of each FP used in this study*

Type of FPs	Ratio (v/v)
FP 1	1:5,000
FP 2	1:5,000
FP 3	1:5,000
FP 4	1:5,000
FP 5	1:10,000

*pre-selected from previous study [18].

Experimental setup

As mentioned above, the purpose of this study was to obtained scientific data of treating polluted water by FPs. If there was any improvement of polluted water after application of FPs, this study expected to clarify whether it was due to self-purification of polluted water or activity of FPs. Therefore, six reactors with the effective volume of 20 liters were set up for each polluted canal experiment. Besides the 'Control' reactor (without FP addition), five reactors were set up with addition of five different types of FPs (FP1 to FP5). The addition of FPs was done only once at the beginning of the experiment. The experimental setup is shown in Figure 1.

The mixed water (FP + polluted water) was agitated continuously for three days of operation with air diffusers. Unfiltered water samples were taken from the 20–L reactors on Days 0, 1 and 3 for subsequent parameters, i.e., pH, DO, non-filtered COD (COD_T), non-filtered BOD (BOD_T) and SS analysis. All parameters were analyzed according to the Standard Methods procedure [19] as tabulated in Table 4. Due to the published page limitation, the analytical results were described and discussed only by mean. Standard deviation (SD) values (or error bars) could not be clearly shown here because of several graphical lines.

Table 4 Analytical method

Parameters	Analytical Methods
SS	Gravimetric method
DO	DO meter
pH	pH meter
COD	Closed reflux
BOD	Modified Azide method

Results and Discussions

Experiment with polluted water from San Saeb canal

Figure 2 illustrated the treated water quality during three days of aeration. The initial pH values of all test units including the Control unit were in the narrow range of 7.2–7.4 as shown in Figure 2a, which could be said that the FPs addition did not affect pH quality of polluted water from San Saeb canal. After three days of operation, the final pH values were in the range of 6.9–7.1, which was not evident enough to conclude their decrease.

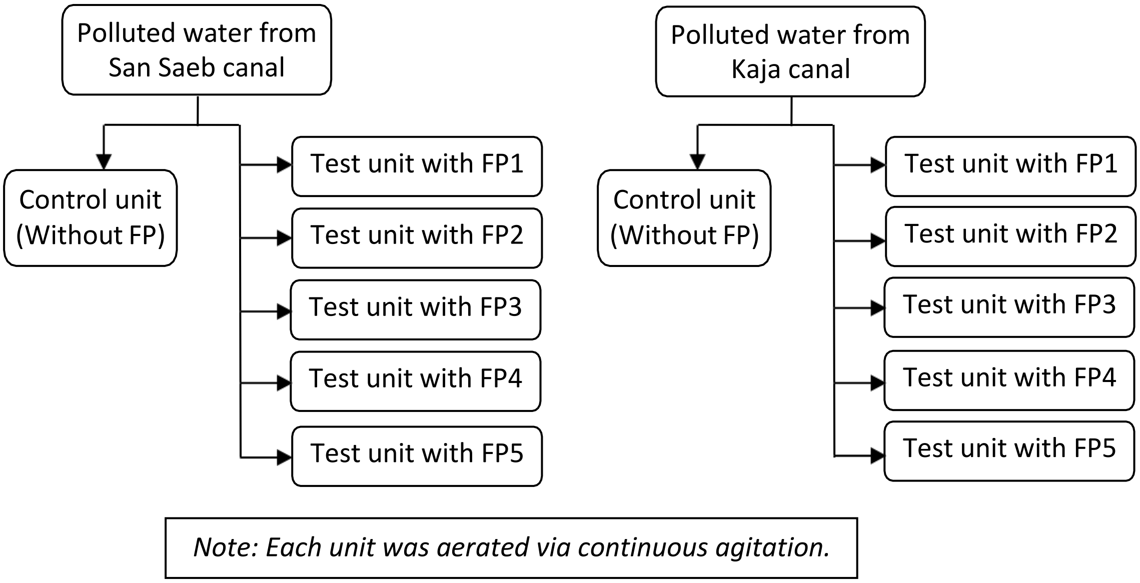

Figure 1 The experimental setup

In case of DO, Figure 2b showed that the initial DO of polluted canal water (both of test units and Control unit) was about 2.2 mg/L. After FP addition, DO levels of the mixed solutions instantly decreased to the range of 1.6–1.8 mg/L, then increased to the higher range of their initial values throughout the three days of operation. The instant decline of DO at Day 0 could be due to the increase of organic loading from the addition of FPs. Moreover, DO increase in this study should be due to the aeration and possibly low BOD loading in polluted water. Interestingly, the highest DO throughout the operation was observed in the Control unit.

For COD_T, as illustrated in Figure 2c, it is apparent that with FP addition, the COD_T concentrations increased from 52 mg/L to the range of 87–107 mg/L on Day 0 due to high organic content in FPs. This is generally known that high concentration of organic carbon in FPs was from the fermentation of molasses in which their COD was normally in the range of 80,000–100,000 mg/L [20]. On the last day of operation, COD_T in every test unit, including the Control unit, were decreased to the range of 25–42 mg/L. The lowest COD_T was observed in the test unit with FP5 addition.

Figure 2d showed BOD_T results from all test units, the BOD_T reduction patterns were consistent to COD_T reduction, except the Control unit. Though BOD_T of the polluted water mixed with FPs, which were in the range of 21–25 mg/L, did not show obvious difference from BOD_T of the Control unit (22 mg/L), all test units with FPs addition still observed BOD_T reduction after three days of operation. The BOD_T concentrations on Day 3 of all test units with FPs addition were in the range of 9–15 mg/L. However, the BOD_T pattern of the Control unit were different, that is, they increased to 36 mg/L on Day 3. Though this analytical BOD_T result was double-checked and could not found any reasonable flaw, this BOD_T (36 mg/L) was quite abnormal as its corresponding COD_T were almost identical (41 mg/L). Anyway, other experiments with the same polluted canal water in the same project was not observed this kind of abnormality.

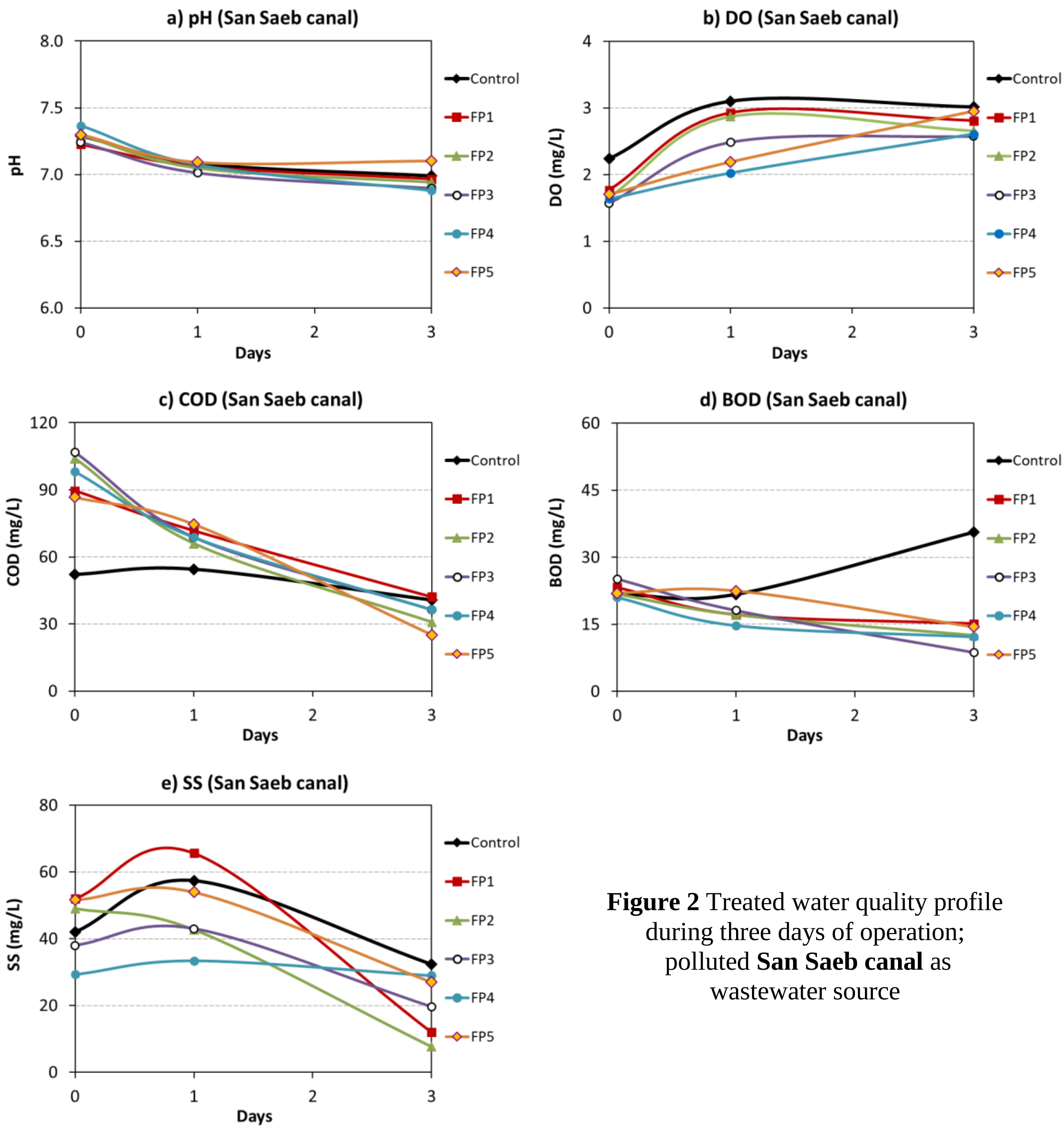

Figure 2 Treated water quality profile during three days of operation; polluted **San Saeb canal** as wastewater source

For suspended solids (SS), in this case was not totally related to the treated effluent quality, but rather bacterial mass. After FPs addition (Day 0), SS concentrations (29–52 mg/L) were observed both higher or less than those of the Control unit (42 mg/L) as shown in Figure 2e. On Day 1, all test units including the Control unit showed the increase of SS, which should be the result of the increased bacterial mass from the utilization of available carbon source in both the canal water itself and FPs. Nevertheless, the SS reduction was also observed after three days of operation in all test units. The final SS concentrations in the range of 8–29 mg/L were found in those test units with FPs addition, while that of the Control unit was 32 mg/L. Obviously, the addition of five different FPs did not perform a distinguished advantage over the no-FP case.

Experiment with polluted water from Kaja canal

In this experiment, the polluted water sample was taken from Kaja canal and divided into six test units, one of which were a Control unit and other five units were with FPs addition. The treated water quality of the polluted Kaja canal after three days of aeration was demonstrated in Figure 3. The initial pH values with FPs addition were mostly identical to the Control unit (of about 7.2). After three days of operation, some test units were almost the same as their initials while some showed little increase to the range of 7.3–7.4 as shown in Figure 3a.

For DO characteristic, Figure 3b illustrated that the DO level of the Control unit clearly increased from its initial concentration of 2.1 to 3.5 mg/L on Day 3. Also, DO levels in all test units with FP addition increased from its initial range of 2.0–2.1 mg/L to the final range of 2.7–3.0 mg/L. This could be explained that oxygen supply from aeration should be more than enough for bacterial respiration in all test units. However, FPs addition brought more organic content into the units, therefore, more oxygen consumption would be expected.

Figure 3c showed that the initial COD_T in all test units were in the range of 81–117 mg/L and tended to decrease to the range of 46–60 mg/L on Day 3 of operation. Among all test units, these final COD_T levels were almost similar to each other, which should be implied that this leftover COD_T would not be further easily biodegradable. In addition, these test units with FP addition did not perform better COD_T reduction than that of the Control unit.

The BOD_T reduction patterns for all test units including the Control unit in Figure 3d showed that the initial BOD_T in the range of 35–45 mg/L decreased to the range of 14–19 mg/L on Day 3. In comparison with the Control unit (without FP addition), there was no apparently better efficiency of BOD removal in test units with FPs addition.

In case of SS, the results shown in Figure 3e were similar to those experiment with polluted water from San Saeb canal (in previous section). SS levels in all test units with polluted water from Kaja canal increased from the range of 21–30mg/L to 20–36 mg/L on Day 1, and then decreased to the range of 8–24 mg/L on Day 3.

Effects of fermented products addition

From the results as shown in Figures 2 and 3, it was quite clear to mention that the addition of FPs gave no different performance in both the Control (without FP) and all five test units (with PFs addition). The results also illustrated the increase of final DO from their initials in every unit as the organic concentrations (BOD_T) decreased. Despite the “high dilution ratio” of FP addition (1:5,000 or 1:10,000), the initial organic concentrations (both BOD_T and COD_T) were still raised up a little in comparison to the ‘Control’ due to most fermented products contained high organic component from their fermentation process.

Both BOD_T and COD_T reduction patterns for polluted waters (San Saeb and Kaja canals) in this study did not clearly show distinguished treatability between FP addition (five FP types) and no-FP case. For an instance, the COD_T on Day 3 of the Control unit in Kaja canal experiment was even better than those with FPs supplement (Figure 3c). Though the actual mechanism of water purification occurrence in these reactors (with FPs addition) could not be evidently explained, these results scientifically confirmed that indigenous microorganisms also performed similarly or even better. The researchers from Wageningen University attempted to study the effectiveness of EM and concluded that EM is not effective, at least under their study conditions [21].

Moreover, adding FPs could increase the SS on Day 1, which was the result of the increased bacterial mass from the consumption of carbon source available in FPs themselves and polluted waters. These results were inconsistent with some researchers, which reported their success in using certain FPs in wastewater treatment [12, 22].

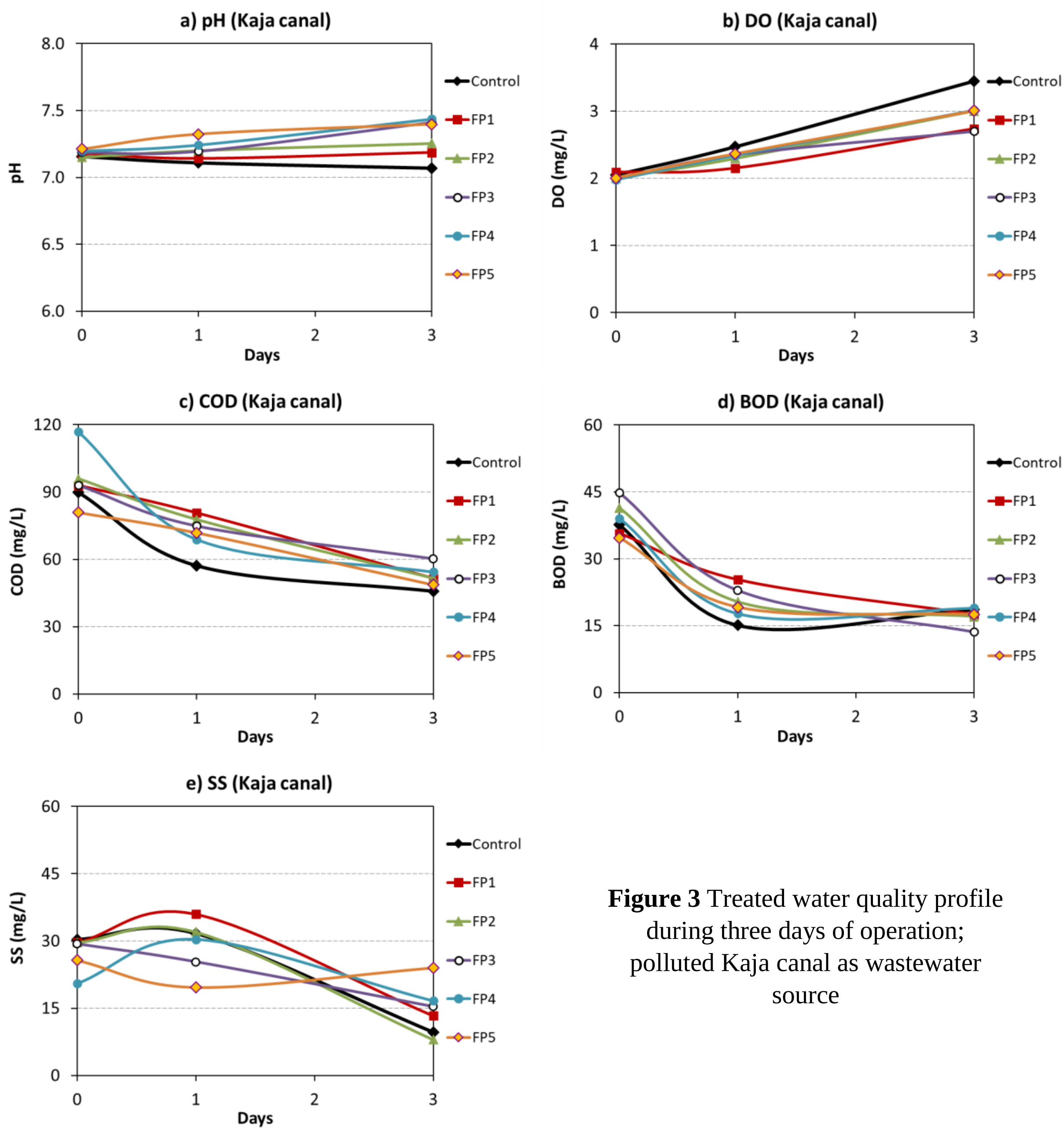

Figure 3 Treated water quality profile during three days of operation; polluted Kaja canal as wastewater source

The indistinctive advantage of the FP supplement may be to increase bacterial mass (represented by SS values) in less time, which would be useful for startup process. However, this is at additional cost (or expense) while the bacterial mass (MLSS) can be enhanced through a conventional startup procedure if one knows how to do the job. Besides, if most of bacteria contained in FPs were produced from the anaerobic fermentation process, the benefit for startup process in aerobic treatment would still be doubtful.

Several FP manufacturers and EM supporter used to claim their products were enriched with PNSB, resulting in high photosynthesis. In contradiction, low PNSB was found in these FPs applied in this study [17] (as shown in Table 2). It is also noteworthy that polluted canals are septic and if the high COD removal has to be anticipated, huge investment through the aeration for whole canal to get complete aerobic condition will have to be encountered. Therefore, this is not consistent with the claim from FP manufacturers and their believers that their products can increase the oxygen level in any polluted canals due to the photosynthesis. Moreover, this illusion of photosynthesis emitting oxygen to the atmosphere needs to be clarified, especially photosynthesis by bacteria. Unlike vegetational photosynthesis, this bacterial photosynthesis did not produce oxygen. There are about five groups of bacteria doing photosynthesis; green sulfur bacteria (GSB), green non-sulfur bacteria (GNSB), purple sulfur bacteria (PSB), purple non-sulfur bacteria (PNSB) and cyanobacteria [23].

Conclusions

The addition of five fermented products (FPs) into raw polluted water from two designated canals in Bangkok could increase the initial COD_T organic concentration from 52 mg/L to the range of 87–107 mg/L. There was no clear-cut conclusion on the benefit of the FP addition in terms of COD_T and BOD_T reduction. It was apparent that the five FPs gave similar treatment results, as well as, all performance of the test units (five FPs) were similar to the Control one (some were even worse). This could be said that water purification of polluted canals did not require FP addition actually. The only advantage of the FP supplement was the increase of SS or bacterial mass in less time, which was preferable for startup process. It was postulated that not much odor reduction was to be achieved, due to very low PNSB found in the FPs. The claim that the FPs can increase the oxygen-level in any polluted canals should be therefore misleading information.

Acknowledgement

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