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Treatment Efficiency of High Organic-Concentrated Wastewater from Pla-Som Production by Combined Treatment System

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ABSTRACT

The research aims to determine the appropriated period of hydraulic retention time (HRT) for treating high organic-concentrated wastewater from pla-som production by the combined treatment systems of 50-mm plastic screen, five 3.5 m^3 oil-grease trap tanks (2-day HRT), four 2.1 m^3 anaerobic tanks (1-day HRT), 16.7 m^3 oxidation pond one (7-day HRT), 12 m^3 oxidation two (3-day HRT), and 8.2 m^3 plant filtration plot (1-day HRT). The production of the wastewater was from the process of washing fresh raw fishes, the raw fishes were sliced in small pieces and converted into ground fish meat by the blender machine. The fish meat was rinsed for 8 rounds with the 1, 2, 3, 5, 6 and 7 by rice-wash-water and the 4 and 8 rounds by tap water before mixing with salt, garlic, steamed rice and monosodium glutamate. This is followed by plastic wrapping for 48-day before edibility. During pla-som production processing, the rinsed wastewater about 7 m^3/day was fed to the treatment systems and fully stagnating storage in its components. The 700-kg raw fish was taken as wastewater producer which had to be treated by the said treatment systems. The result was satisfied in treatment efficiency with 32% for TDS, 98% for SS, 93% for BOD, 95% for COD, 81% for TOC, 100% for oil and grease, 53% for TKN, 66% for ammonia and 50% for total-P. However, it was still not favorable for quantitative quality of TDS, SS, BOD, COD, TOC, TKN, ammonia, Total-P, and phosphate due to the slow bacterial organic digestion rates from inhibiting garlic and salt components of the wastewater. The results evidently indicated that the contaminants of small pieces of fish meat and fish blood needed more than 3-day HRT in the trapping oil-grease and anaerobic tanks rather than aerobic oxidation ponds and plant filtration plot for providing anaerobic organic digestion process. Changing the first oxidation pond into another anaerobic tanks is surely expected to add more 7-day HRT which becomes to 8-day HRT for converting small pieces of fish meat and fish blood into inorganic materials through an anaerobic digestion process.

Key words : *Treatment efficiency, Pla-Som production, Combined treatment systems*

Introduction

Kwan Payao is one of among three natural lakes that plays an important role as a water storage reservoir locating in the upper north of Thailand. It provides not only resources for local consumption but also protein-fish production, it also provides irrigation as another function for paddy rice fields located in the downstream areas as the outlet from the lake have allowed for farmers to obtained water yield availability (quantity, quality, and flow regime) for maintaining their livelihoods. However, the Kwan Phayao lakefront people have been overusing water resources of the lake in the upstream and downstream areas for recent two decades, causing water problems to shined on the areas, especially during the dry period due to siltation, community wastewater, unbalancing aquatic plants to herbivore fish growth rate, and abundant cover with water hyacinth. The problems were further escalated with particularly the production of herbivore fish products (Pla-som) using the summer flow irrigation. Nowadays, Kwan Phyao lake has becomes more shallow together with the warning stage of polluted reservoir causing low fish productive resources, and water quality for waterworks.

Pla-som or traditional fermented fish product that is the local preserved protein food which have been cooked for very long period of time owning to its natural abundance to scale fishes living in the Kwan Phayao lake. Pla-som is also known as the traditional fermented fish that can also be called sour fish as it has been made since in the ancient time for preserving fishes as the protein food. In the past, pla-som used to be necessary traditional preserved food like pla-ra, pla-jom, pla-kem (salted fish) and pla-haeng (dried fish) for take-away protein food for the farmers and travelers whenever they were away from homes for their missions (Little *et al.,* 1996; Lee, 1997; Westby *et al.,* 1997; Ostergaard *et al.,* 1998; Scurlock *et al.,* 2000; Adler and Benchat, 2002; Nurhasan *et al.,* 2010). Among those preserved fish, pla-som is the most favorite protein food due to its sour taste which is accepted as good appetizer as well as easiness in cookery. Normally, making pla-som could be cooked by mixing raw slice-off fishes (scale fishes preferable) with garlic, salt, steamed rice, and a pinch of seasoning powder along with fresh banana leaf and preserved for 4 days (Paludan-Muller *et al.,* 1999; Kopermsub and Yunchalard, 2001; Paludan-Muller *et al.,* 2002; Riebroy *et al.,* 2008; Bernbom *et al.,* 2009). In the past these processes do not cause many environmental problems as they are only done in a home-made production, low-populated density, and biotic potential surroundings at that period. However, the production process has been gradually modified from the old days up to the present time and that in the future have been encouraged to increase. This would then cause larger pollutants spreading into the environment, especially wastewater. In the same manner, lakefront people have also modified pla-som cookery methods of grinding the fish into small pieces together with rinsing by water of washing rice for adding up sour taste. Certainly, this new method has produced more wastewater plus contaminants from fish scarps, blood, and fats which are composed of high nitrogen from protein in fish meat, phosphorus and iron as the same as another element from blood, and oil and grease from fats (Camphell-Platt, 1994; Valyasevi and Rolle, 2002; Roos *et al.,* 2007).

From the current situation, the consequent problems of the high protein contaminant wastewater produced from the production process that were drained into Kwan Phayao lake has bring about many environmental impacts to the well-being of the local community. Although there have been some producers whom were concerned on the wastewater problems, the main issue was rather not knowing of how to treat it. This weakness gap has caused the water resources of the Kwan Phayao to become increasingly worsened, noticeably the water quality of that has been identified as under the surface water quality standards on the third to fourth levels (BOD equivalent between 2.5-4.0 and 4.0-6.0 mg/L) as these results were far from raw water quality requirement for waterworks being on border line survival of aquatic lives. Knowing that the point sources of the wastewater are mainly coming from family-industrial factories for pla-som production which exists more than 30 factories and tends to increase without care for treating wastewater. Consequently, wastewater from the pla-som production process has to be treated before releasing into Kwan Phayao lake in order to keep water resources clean for serving any purposive consumption, especially aquatic lives surviving.

In principles, the high concentrated community wastewater is usually treated by the anaerobic processes in order to decrease the organic matters, especially high content of nitrogen and phosphorus, down to standard values before releasing into public water sources, but the length of hydraulic retention time (HRT equivalent to volume anaerobic tank divided by influent flowrate) plays vital role in treatment (Metcalf and Eddy, 1974, 1979; Nopparatanaporn, 1992; Ugwuanyi *et al.,* 2005;

Slade *et al.,* 2011; Mangimbulude *et al.*, 2012; DOPC 2013). In other words, more HRT will create the high the treatment efficiency (Metcalf and Eddy, 1974, 1979; Ladu and Lu, 2014; Marino-Solis *et al.*, 2015; Michael-Kordatou *et al.*, 2015). If the concentration of contaminants is not decreased to effluent standards, the oxidation pond technology should be used for receiving the effluent water in order to allow for hydrogen sulfide, ammonia, methane, carbon dioxide, and other gasses to escape, while the sinking oxygen in the air can also penetrated into the bottom by photosynthesis and thermo-siphon processes (Metcalf and Eddy, 1974, 1979; Renolds and Edwards, 1995; Mirnov and Belyakava, 1982; Ameth and Stichimair, 2001; Tumar and Suthar, 2011; Chunkao *et al.,* 2012), together with growing the water hyacinth in bamboo-frame raft covering 20-percent oxidation-pond surface (Ready *et al.,* 1990; Sooknah and Wilkie, 2004). If the retreated effluent quality is still over standards but the BOD is less than 300 mg/L, the constructed wetland (either one or both vertical and horizontal flow) is recommended to absorb nitrogen and phosphorus content before draining into public streams (Boyd, 1970; Juwarkar *et al.*, 1995; Kayser and Hunst, 2005; Molle *et al.,* 2008; Kantawanichkul *et al.,* 2009; Vymazal, 2010; Liu *et al.,* 2012).

The aforesaid information is expectedly applicable for high concentrated wastewater treatment from pla-som family industrial factory by the combined treatment system using oil-grease trap tanks, anaerobic tanks, oxidation ponds and constructed wetland before draining effluent into Kwan Phayao lake as this experimental research is expected to improve the water quality of Kwan Phayao lake and surviving aquatic lives.

Materials and Methods

The experimental system was comprised of one 50-cm plastic screen, five 1.2-m (diameter) ferro-concrete-circle tanks using for three oil-grease trap tanks and two anaerobic tanks, 16.7-m^3 for the first oxidation pond, 12.0-m^3 second oxidation pond, and 8.2-m^3 plant filtration plot (Figure 1). An application flow chart was illustrated in Figure 2 that showed the started up process linking to the wastewater obtaining define by from the rinsing water of the carp fishes (*Hypophthalmichthys nobilis*) before and after slicing them into separate production line of fish meat plus skin and other by-products (heads, intestines, fishbone, skeletons, and scales). Then after, the sliced fish meat and skin were ground into fine texture by a blender in which the fish meat was required to rinse for 8 rounds: rounds1, 2, 3 and 5, 6, 7 washing by rice-wash water, and specifically rounds 4, 8 by tap water from public water system. From the experimental point of view, the 100-kg fish meat needs to be supply with 5.2-kg garlic, 4.4-kg salt, 1.7-kg steamed rice and 1.6-kg monosodium glutamate to mix with before wrapping by plastic bag and sending to the wholesaler. For by-product benefits of fish head was also sold out for boil rice cooking ingredients or directly for raising livestock's animals. The fishbones, skeletons, and scales were ground to make tablet food for raising catfishes. For focusing on this research paper, the emphasis was placed on the appropriate HRT period for treating on high concentrated-content wastewater from pla-som production process which presented in Figures 1 and 2.

Following the APHA, AWWA, WEF (2005), water samples were taken at outlets of family industrial factory, screen, before and after oil and grease traps, outflow from anaerobic ferro-concrete circular tanks, 30-cm and 0.8-h (0.8 ratio of the total depth) depths of oxidation ponds 1 and 2, plant filtration plot at top, middle, tip and outlet. The water samples were analyzed on the water quality indicators of temperature, pH, DO, EC, salinity, TDS, SS, BOD, COD, TOC, Oil and Grease, TKN, Ammonia, TP, and phosphate.

Owning to find out the hydraulic retention time (HRT), the experiment was divided into a phase by phase unit until the final effluent was drained out from the treatment system meeting the standard values under the various conditions of anaerobic organic digestion process. In doing so, the experiment was repeated many times as due to the highly concentrated wastewater from pla-som factory were found to be very complicated, especially the BOD concentrations that were as high as 10,000 mg/L

Results and Discussion

In application of the thirteen-day HRT efficiency that utilized only five-ferro-concrete circle tanks, three for oil and grease trap tanks and another two anaerobic tanks which included only one line of anaerobic tanks (Figure 1).

In principles, the water supply is utilized for three main rinsing activities, i.e., cleaning fresh fishes (averaging 60 L/100-kg fishes), washing off fish meat (averaging 800 L/100-kg fishes), cleaning the floor and cooking instruments (averaging 140 L/100-kg fishes). According to research requirement to determine the minimum requirement for the HRT for anaerobic organic digestion processes inside anaerobic tanks under the stagnating condition, the amount of wastewater produced was 7 m^3/day as this was used for washing fresh fishes (totally 700 kg) and fish meat which was drained out by gravitational force to fill in full storage tanks of 42.5 m^3 then moving into the three oil and grease trap tanks 3.5 m^3 (2-day HRT) before storing in two anaerobic tanks 2.1 m^3 (1-day HRT) then moving into oxidation pond one 16.7 m^3 (5-day HRT) oxidation pond two 12.0 m^3 (4-day HRT), and lastly to the plant filtration plot 8.2 m^3 (1-day HRT) with the total accumulative 13-day HRT.

It can be visualized during production process produced high contents of oil-grease, fish blood and small pieces of fish meat that was mixed in with the concentrated wastewater after taking pla-som cookery processes from production area. However, the results of experiment were presented in Table 1 which were provided to the conditions for treating efficiency of high organic-concentrated wastewater from pla-som production process as shown in Table 2.

The result suggested that the ambient temperature was placed on the narrow ranges of 2.2 °C (between 23.8-26.0 °C) which is supposed to influence on the biochemical reaction of both the anaerobic and aerobic processes inside the fermented tanks and oxidation ponds together with the Typha

Treatment type	Volume (m^3)	HRT (day)
Oil and grease trap	3.5	2
Anaerobic tank	2.1	1
Oxidation pond 1	16.7	5
Oxidation pond 2	12.0	4
Plant filtration	8.2	1
Total	42.5	13

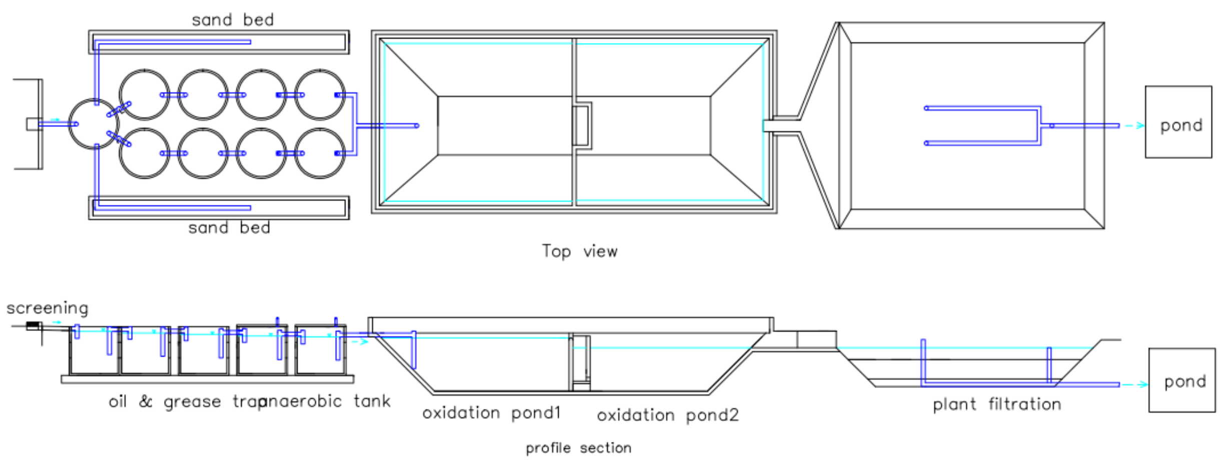

Fig. 1. Schematic illustration of onsite combined treatment systems for high concentrated wastewater from pla-som family industrial factory at Kwan Phayao lake, Phayao province, Thailand.

Table 1. Water quality as significant conditions for providing treatment potentiality of high organic-concentrate wastewater from pla-som production processes of family-industrial factory at Kwan Phayao, Phayao province, Thailand

Sampling Point	Ambient Temp (°C)	Water Quality Indicator				
		Temp (°C)	pH	DO (mg/l)	EC (µS/cm)	Salinity (g/l)
Effluent of Production Process	26.0	24.3	6.3	0.00	2,760	1.3
Effluent of Screening	26.0	25.9	6.5	0.00	3,730	1.0
Influent of Oil and Grease Trap Tanks	26.0	26.4	6.6	0.00	3,650	1.1
Effluent of Oil and Grease Trap Tanks	25.3	27.8	6.2	0.06	2,433	1.2
Effluent of Anaerobic Tanks	24.7	28.3	6.4	0.06	2,650	1.4
30-cm Depth of Oxidation Pond 1	23.9	28.9	6.5	0.10	3,093	1.6
0.8 h Depth of Oxidation Pond 1	23.9	26.4	6.6	0.11	3,053	1.6
30-cm Depth of Oxidation Pond 2	23.8	26.6	7.1	0.07	2,733	1.4
0.8 h Depth of Oxidation Pond 1	23.8	26.1	7.2	0.05	2,790	1.4
Plant Filtration Plot (Top,1-m)	23.8	26.1	7.5	0.00	2,423	1.2
Plant Filtration Plot (middle,3-m)	23.8	26.4	7.5	0.00	2,406	1.2
Plant Filtration Plot (Tip,5-m)	23.8	26.6	7.5	0.00	2,108	1.1
Effluent of Plant Filtration Plot	23.8	27.3	7.3	0.06	2,193	1.1
Water Quality Standard	-	40.0	5.5-9.0	-	-	-

Remarks: Measurement of ambient air temperature at 07.00 a.m.

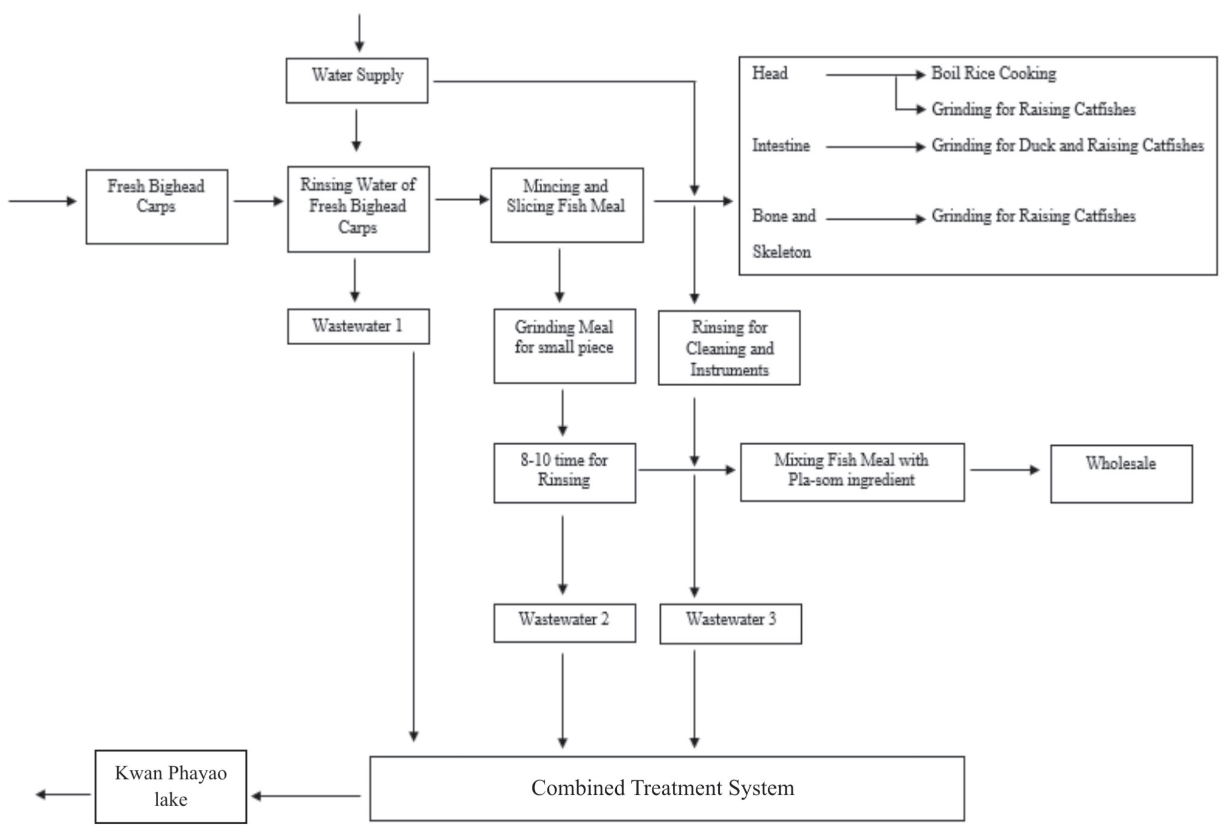

Fig. 2. Flow chart of onsite combined treatment systems for high concentrated wastewater from pla-som family industrial factory at Kwan Phayao lake in northern Thailand.

aquatic plants (*Typha angustifolia* linn.) as grown in the plant filtration plot. The salinity ranged from 1.01-1.60 g/l seemed to take an action on biochemical processes by inhibiting microorganisms for digesting small pieced of fish meat in terms of slowing down the process and taking more HRT. Expectedly, there were some gases emitting to the open area due to mostly digestion was not reach at the end of biochemical processes or the methanogenesis progress but unto the hydrolysis and acidogenesis processes (Metcalf and Eddy, 1974,1979; Camphell-Platt, 1994; Leverenz *et al.,* 2002; Paludan-Muller *et al.,* 2002; Chunkao *et al.,* 2012; Ladu *et al.,* 2014). Furthermore, the values water quality indicators in Table 1 were influenced in the minor negative biochemical interactions, as they were temperature, pH, EC, and DO in all instruments of treatment system (Metcalf and Eddy, 1947,1979; Nopparatanaporn, 1992; Nout, 1994; Lee said, 1997; Westby *et al.,* 1997; Scurlock *et al.,* 2000; Leverenz *et al.,* 2002; Paludan-Muller *et al.,* 2002; Valyasevi and Rolle, 2002; Ugwuanyi *et al.,* 2005; Roos *et al.,* 2007; Kopermsub and Yunchalard, 2010; Mangimbulude *et al.,* 2012; Pattamapitoon *et al.,* 2013). In other words, the water quality indicators in Table1 suggested that there were in minor impacts on the treatment efficiency due to dilution of water supply from washing fresh fishes, fish meat, and cleaning floor and instrument. Besides salt as one of the ingredient of pla-som cookery, garlic was also added for serving the purpose of smell, taste, and physical healthcare however it also plays vital role in inhibiting bacterial decomposers as found in wastewater from pla-som production process (Paludan-Muller *et al.,* 1999; Adler *et al.,* 2002; Riebroy *et al.,* 2008; Bernbom *et al.,* 2009). Luckily, washing water was supported the dilution of garlic content in wastewater that is not strong enough to kill all species of microorganisms.

The original wastewater was directly obtained from the pla-som production processes inside the factory as shown in in Table 2. They were found as follows, TDS 2,208 mg/l, SS 11,963 mg/l, BOD 10,633 mg/l, COD 20,200 mg/l, TOC 2,874 mg/l, oil and grease 1,878 mg/l, TKN 274 mg/l, ammonia 286 mg/l, total-P 22 mg/l, and phosphate 19 mg/l. Those values could be accepted, however with extremely high concentration, they are very difficult to treat them under the royal nature-by-nature process as it needed not only the anaerobic digestion processing tanks but also the oxidation ponds with

Table 2. Water quality of qualitative values and treatment efficiency in percentage under the condition of consecutively flowing from pla-som production area to the 50-mm plastic screen, 3 oil and grease trap thanks, 2 anaerobic tanks, oxidation ponds1 and 2, and plant filtration plot

Sampling Point	Water Quality Indicator (mg/l)									
	TDS	SS	BOD	COD	TOC	G&O	TKN	Ammonia	TP	Phosphate
Effluent of Production Process	2,208-	11,963-	10,633-	20,200-	2,874-	1,878-	274-	286-	22-	19-
Effluent of Screening	2,984(-34)	10,706(11)	9,633(9)	19,850(2)	1,654(42)	1,566(17)	528(-93)	270(6)	24(-10)	27(-44)
Influent of Oil and Grease Trap Tanks	2,920(-32)	2,396(80)	3,710(65)	6,720(67)	930(68)	336(82)	235(14)	256(10)	15(31)	66(-245)
Effluent of Oil and Grease Trap Tanks	1,629(26)	253(98)	1,518(86)	2,158(89)	513(82)	32(98)	226(18)	265(7)	31(-42)	61(-223)
Effluent of Anaerobic Tanks	1,783(19)	247(98)	1,289(88)	1,403(93)	612(79)	29(98)	215(22)	243(15)	30(-38)	121(-538)
30-cm Depth of Oxidation Pond 1	2,070(6)	122(99)	1,216(89)	1,828(91)	855(70)	16(99)	261(5)	209(27)	24(-8)	23(-23)
0.8 h Depth of Oxidation Pond 1	2,046(7)	101(99)	980(91)	1,905(91)	856(70)	14(99)	259(5)	197(31)	33(-49)	23(-23)
30-cm Depth of Oxidation Pond 2	1,845(16)	120(99)	897(92)	1,435(93)	733(74)	9(100)	231(16)	183(36)	23(-4)	21(-12)
0.8 h Depth of Oxidation Pond 1	1,835(17)	231(98)	965(91)	1,602(92)	741(74)	11(99)	243(11)	162(43)	48(-120)	86(-351)
Plant Filtration Plot (Top, 1-m)	1,614(27)	264(98)	764(93)	1,150(94)	607(79)	3(100)	188(31)	145(49)	27(-22)	101(-432)
Plant Filtration Plot (middle, 3-m)	1,629(26)	144(99)	970(91)	1,167(94)	600(79)	4(100)	183(33)	168(41)	18(17)	97(-410)
Plant Filtration Plot (Tip, 5-m)	1,432(35)	152(99)	765(93)	951(95)	401(86)	3(100)	131(52)	158(45)	23(-5)	64(-236)
Effluent of Plant Filtration Plot	1,499(32)	256(98)	780(93)	1,097(95)	547(81)	2(100)	157(53)	98(66)	11(50)	87(-357)
Water Quality Standard	3,000	50	20	120	-	5	100	-	-	-

Remarks: Numbers in parenthesis identified as percentage of treatment e aerobic process through thermo-siphon process and phytoremediation techniques through thermo-osmosis process (Boyd, 1970; Westby *et al.,* 1979; Mirmov and Belyakava, 1982; Juwarkar *et al.,* 1995; Ameth and Stichimair, 2001; Kayser and Hunst, 2005; Molle *et al.,* 2008; Kantawanichkul *et al.*, 2009; Vymazal 2010; Tumar and Suthar, 2011; Lio *et al.*, 2012).

The study on the consecutive ponds from the pla-som wastewater treatment shows the decreasing and increasing trends of water quality values (Table 2). This was found out that the end products were extremely decreased and/or increased as they were still above the standard values. Also, the unpleasant smells of gases that was emitted from the pla-som wastewater treatment system has caused negative impacts to surrounding people in working and sleeping. In fact, the most important role in the whole anaerobic treatment system was placed under the efficiency of anaerobic ferro-concrete circle tanks because of the existence of its function. By those reasons, reconsideration of treatment trends at the outlet of anaerobic tank was pointed out that the decreasing values were high efficiency such as 19% for TDS, 98% for SS, 88% for BOD, 93% for COD, 79% for TOC, 98% for oil and grease, 22% for TKN and 15%.

It would be to stressed that these percentages in efficiency were satisfied however, the water quality values were still high above the standards. This should be noted that the nitrogen content has been varied in various forms as this was the same with phosphate and total-P due to the high quantitative blood content in wastewater and also the area of the onsite wastewater treatment being used for raising ducks and hens for long periods of time.

In principles, the small pieces of fish meat and blood are required to convert them from organic matters to inorganic materials through anaerobic process rather than aerobic processes. So, only 3-day HRT (2-day HRT in oil-grease trap tanks and 1-day HRT in anaerobic tanks) were implemented for converting the small pieces of fish meat and fish blood into inorganic materials. However, this does not decrease wastewater quality to meet the effluent water quality standards after draining out from Typha aquatic plant filtration plot. In order for the applicability for high concentrated-organic contaminants, a next treatment experiment is recommended to be conducted as the increasing HRT period for anaerobic process, for implementing, the oxidation pond one should be covered for anaerobic process which provides another 5-day HRT for digesting small pieces of fish meat and oil-grease contaminants.

Conclusion

High concentrated organic content in wastewater from pla-som family industrial factory was treated under the combination of anaerobic process, oxidation ponds, and through the *Typha* aquatic plant filtration plots by dividing the experiment into two treatments with the results presented as followed:

The 700-kg raw fish usage for pla-som cookery produced wastewater with the contaminants of TDS at 2,208 mg/l, SS 11,963 mg/l, BOD 10,633 mg/l, COD 20,200 mg/l, TOC 2,874 mg/l, oil and grease 1,878 mg/l, ammonia 286 mg/l, total-P 22 mg/l and phosphate 19 mg/l. After treating with the 2-day HRT, for 3 oil-grease trap tanks, 1-day HRT for 2 anaerobic tanks, 5-day HRT for oxidation pond one, and 4-day HRT for oxidation pond two and 1-day HRT for plant filtration plot, the overall treated efficiencies were 32%. With efficiencies for the other parameters were 32% for TDS, 98% for SS, 93% for BOD, 95% for COD, 81% for TOC, 100% for oil and grease, 53% for TKN, 66% for ammonia, 50% for total-P, and -357% for phosphate. The findings were satisfied in terms of efficiencies but the experimental values of effluent quality did not meet the standards. In accordance with small pieces of fish meat and fish blood were really needed an organic digestion processes in anaerobic tanks. The dilution of wastewater did not enhance the rate of organic digestion process either in anaerobic tanks or in oxidation ponds. With only prolonging of 3-day HRT to 10-day HRT is very necessary for converting the small pieces of fishes and blood into inorganic materials for high concentrated wastewater from pla-som production family factory.

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