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Invited Paper

Treatment of Fermented Fish Production Wastewater by Constructed Wetland System in Thailand

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ABSTRACT

Many agro-industries in Thailand discharge untreated wastewater with high organic content causing severe environmental problems. The objectives of this study were to provide a wastewater treatment system for a fermented fish production factory and to demonstrate the constructed wetland technology as an on-site solution for the treatment of wastewater which is economical, and not complicated to operate or maintain. The wastewater from fermented fish production contains BOD, COD, TKN, grease and oil at approximately 6,200, 9,770, 540 and 660 mg/L, respectively. Pre-treatment by a grease trap and an anaerobic process is required prior to two constructed wetland beds connected in series. The first bed is a subsurface horizontal flow bed (180 m^2) filled with stone (1-2 inch) and planted with Umbrella sedge (*Cyperus flabelliformis Rottb*). The second bed is a free water surface bed (140 m^2) planted with Canna (*Canna hybrida*). The designed capacity of the treatment system is 10 m^3/d though presently the maximum volume of wastewater received daily is only 5-7 m^3. The factory operates around 5 days per week and 4 hours per day on average depending on the amount of fish processed. A grease trap and a UASB reactor reduce grease and oil, BOD and COD efficiently but only 50% for TKN was eventually reduced in the two wetland beds. The overall removal efficiencies of the system were over 97% for COD, BOD, SS and grease and oil and was around 70% for TKN and NH_4^+-N. Wastewater from the free water surface bed was reused for gardening.

Keywords: Canna; constructed wetland; fermented fish production wastewater; free water surface; subsurface flow; Umbrella sedge.

1. INTRODUCTION

The treatment system is located in Phayao province 691 km. north of Bangkok.

Fermented fish is one of the famous products of Phayao which provides a high annual income for the province. Production is done by more than twenty families scattered in three villages and the generated wastewater contains very high grease and oil and COD (Chemical Oxygen Demand) levels. To solve this problem, the local authority (Tambon Administration Organization) has provided a central factory-wastewater treatment system. The system is simply composed of septic tank and a subsurface soil absorption field. As time passed, the system was failed due to clogging of the soil filtration bed and there were no alternative methods to treat the wastewater. At the time of the study, there were three production groups working at the factory and untreated wastewater discharge on the grounds caused a negative impact in the form of smelly, polluted water and a subsequent deterioration in health conditions.

The main objective of this study was to construct a wastewater treatment system which is cost- efficient, as well as, easy to operate and maintain which would serve as an example for communities to learn from and later apply to the treatment of other wastewaters. A constructed wetland system was selected because of it's simplicity and promising low construction and operation cost (Cooper,1999, Brix,1993). This demonstrative project was funded by CIDA-AIT SEA-UEMA (The Canadian International Development Association and the Asian Institute of Technology, whose collaborative project is entitled the South East Asian Urban Environmental Management Application project) under Alumni Demonstration Projects. The objectives of this study were to provide a wastewater treatment system for a fermented fish production factory which will alleviate the water pollution problems caused by the discharge of untreated wastewater. Therefore, to demonstrate the constructed wetland technology as an on-site solution for wastewater management and to build the awareness of the community on good sanitation and hygienic practices.

The local authority at Baan Sang sub-district where the factory is located contributed the land area for the construction of the treatment system and Chia Nan University of Pharmacy and Science served as a co-partner and supported in terms of technology transfer.

2. METHODOLOGY

The designed system was composted of a grease trap, an anaerobic treatment tank (UASB, Upflow Anaerobic Sludge Blanket) and two constructed wetland beds, the first being a subsurface horizontal flow bed, while the second is a free water surface bed. Illustrated in figure 1. With regards to the very high COD and grease and oil levels in the wastewater, pre-treatment by a grease trap and an anaerobic process is necessary to reduce their concentration in the wastewater to the level that wetland system is able to tolerate. The design capacity of the system is 10 m^3/d of wastewater. The treatment system consists of the following components:

2.1 Grease Trap: A modified concrete tank with the dimensions of $1.5 \times 3 \times 2.3$ m^3 (W×L×d), the tank was divided into two equally-sized parts. The wastewater was collected in the first section where grease and oil are separated, clear water then passes on to the second section which acts as a sump pump and the water was transferred to the UASB tank.

2.3 UASB Tank: The UASB (Upflow Anaerobic Sludge Blanket) tank has dimension of $3 \times 3 \times 4$ m^3 (W×L×d), at the depth of 2 m underground. Half of the wastewater from the UASB tank flowed to the constructed wetland and another half is re-circulated to the sump pump before returning to the UASB a second time.

2.4 Constructed Wetland Beds: There are two constructed wetland beds, the first bed is designed for a subsurface horizontal flow (SSF), and the second bed is a free water surface (FWS) as shown in figure 2. The surface area of the first bed is 180 m^2 (10 m×18 m), filled with stone (ϕ 1-2 inch) for 0.6 m deep. The bed was lined with a plastic sheet to prevent ground water contamination and planted with Umbrella sedge (*Cyperus flabelliformis Rottb*). Umbrella Sedge is a plant species with high value because of its ornamental quality and can grow very well in a subsurface flow constructed wetland system in Thailand (Kantawanichkul et al., 2001; 2003; Kantawanichkul and Somprasert, 2005). The designed hydraulic loading rate was 5 cm/d. The second bed has a surface area of 140 m^2 (10 m×14 m) the water depth is at around 0.4 m, planted with Canna (*Canna hybrida*). Canna grows widely in nature and has colorful flowers which make the system more attractive than just being only a treatment system. Kantawanichkul and Worapan (2007) and Kantawanichkul et.al.(2008) found that Canna is able to treat domestic and fermented fish production wastewater satisfactory in a laboratory scale subsurface flow constructed wetland.

The system was constructed in February 2007 and completed in June 2007. In the mean time, to fulfill the objectives of the project, the producers who work in the factory were required to improve their sanitation in the factory under the guidance of the Provincial Public Health Authority. For example, the building and work area were renovated to improve ventilation and hygiene, They were also required to follow a strict production process. All of the generated wastewater was collected to separate fish debris from the wastewater by filtering as much as possible before its discharge along the pipe to the grease trap.

3. RESULTS AND DISCUSSION

At present, there are three production groups working at the factory. The environment of the factory has improved since the treatment system has been in operation. The producers are satisfied as there is no more odor and the number of flies has been noticeably reduced. Good sanitation around the work area and good environmental care have benefited their products and increased market values. Wastewater was generated from the fish washing process and floor cleaning after work. Analysis of water samples according to the Standard methods for the examination of water and wastewater (APHA, 1998) began in July 2007. During the first four months, only two samples were taken to evaluate the performance of the grease trap and anaerobic tank. The volume of wastewater was under estimated because the other two production groups worked only 2-3 days per week and the water used was less than calculated. The daily flow rate was only about 5-7 m^3 for 5 days a week and 4-5 hours a day in average depending on the amount of fish produced. Samples were taken once a month from the inlet of the grease trap and the outlet of UASB until the macrophytes in the wetlands were fully grown. Subsequently, three more sampling from the wetland beds and the sump pump and analysis was increased to twice a month.

The concentration of the raw wastewater were rather fluctuated depending on the amount of water used in the fish washing process and how good the producers were able to remove fish debris and grease from the discharged wastewater. pH was rather stable around 6.5 on average. However, after pre-treatment in the grease trap and UASB tank, the removal efficiency of COD (Chemical Oxygen Demand), BOD (Biochemical Oxygen Demand), and grease and oil were reduced to satisfactory levels, achieving over 94% and SS (Suspended solids) was at 88% on average. The separation of accumulated grease in the grease trap and long HRT enhanced the removal efficiencies. For nitrogen, the reduction of TKN (Total Kjedahl Nitrogen) and NH_4^+-N (Ammonia Nitrogen) were reduced around 52-53%. Organic nitrogen was converted to ammonia by ammonification and NH_4^+-N was directly incorporated into microbial biomass (Vymazal, 2001).

By October, the macrophytes had fully grown, the wastewater from the second wetland has been analyzed. Wastewater from the first bed was extracted from the gravel bed and analyzed in March 2008. The removal efficiencies were increased after treatment in the constructed wetlands.

However, up to that point in time, wastewater had not overflowed through the outlet pipe of the second wetland and people used this water in their gardens for the contained nutrients.

Overall nitrogen removal efficiency was 70 % on average for both TKN and NH_4^+-N and nitrate increased in the wetland bed as shown in table 1. Therefore, apart from oxidation in the wetlands, most of the nitrogen was assumed to be removed by the consumption of macrophytes and microorganisms including adsorption through a cation exchange reaction with detritus and inorganic sediment (Vymazal, 2001). Photosynthesis by algae which grew densely in the second wetland bed could increased the pH to enhanced nitrogen removal by ammonia volatilization. However, algae growth also contributed to SS and nitrogen in the effluent (Hancock and Buddhavarapu, 1993). Figure 3-7 shows the concentration of BOD, COD, TKN, grease and oil, as well as, SS in the discharged wastewater and the effluent from the UASB tank, the sump pump and constructed wetland beds.

The water quality in the second wetland

Table 1. Characteristics of wastewater on average at each sampling point.

Parameter	Raw wastewater	From UASB	CW bed 1	Pump sump	CW bed 2
pH	6.3	7.5	7.7	7.4	7.7
SS	2,776	309.5	44	503	82.6
BOD	6283.7	253.3	106	271.4	108.4
COD	9,772.8	538.5	169.6	422.6	197.7
TKN	544.4	256.8	245.2	393.4	161.8
NH_4^+-N	480.2	221.8	220.4	351.8	144.1
NO_x-N	0.086	0.17	2.8	0.32	3.4
Grease Oil	663.8	10.5	4.9	7.8	4.9

the effluent of each unit.bed which was the last treatment unit, was under the national industrial effluent standard of Thailand except for BOD. The harvested of Canna caused an open surface which intensified algae growth in the free water surface bed. As mentioned earlier, algae cells contributed to BOD, TKN and SS in the water.

The operation and maintenance of the treatment system properly is very important to make the system sustainable. Cooper,et.al. (2005) indicated five most common problems found in horizontal subsurface flow system were (1) sludge deposition (2) above surface flooding (3) inlet clogging (4) outlet collector incorrect level (5) weed infestation (Cooper, et .al, 2005). The treatment system will be an educational site for students of Chiang Mai University. As the purpose of the project was to build a demonstrative treatment system, it is expected to be a site that other communities can visit and learn.

4. Conclusions

The wastewater treatment system for fermented fish production was constructed to provide a wastewater treatment facility for the factory and to demonstrate constructed

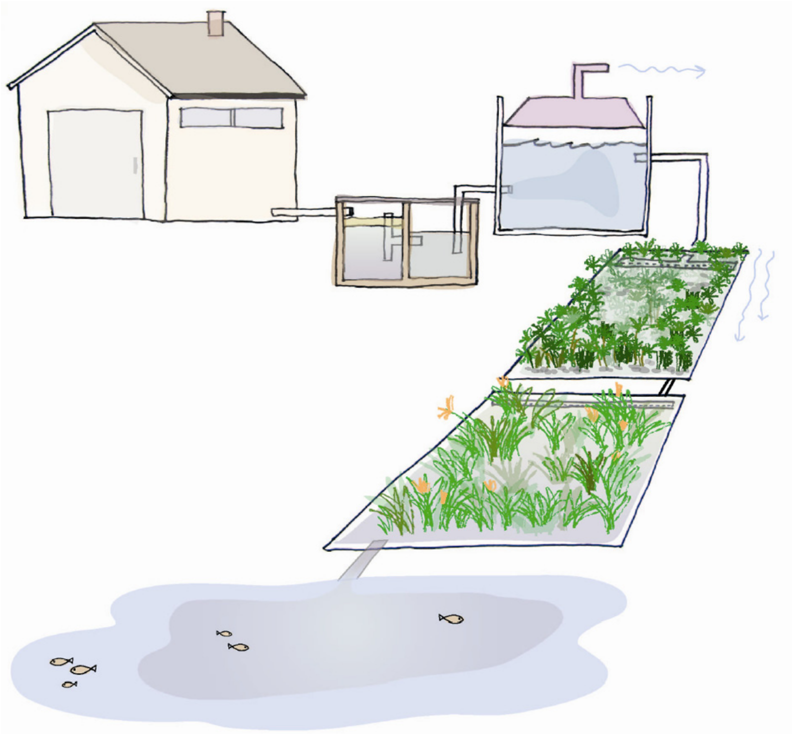

Figure 1. Drawing of the treatment system.

(A) **(B)**

Figure 2. (a) subsurface horizontal flow bed (b) free water surface flow bed.

wetland technology as simple, easy-to-operate, and low-cost for operation and maintenance. At present, the system treats wastewater meeting the national industrial effluent standard of Thailand with the exception of BOD. However, with the system still in its early stages, regular monitoring continues. This project also extended to the application of a natural treatment system by reintegrating treated wastewater with the surrounding environment by following **"**green-technology**"** concepts. Hopefully, this demonstrative project will provide an opportunity for the community to learn through experience. Good management and cooperation between local authorities and users will enhance the system's sustainability.

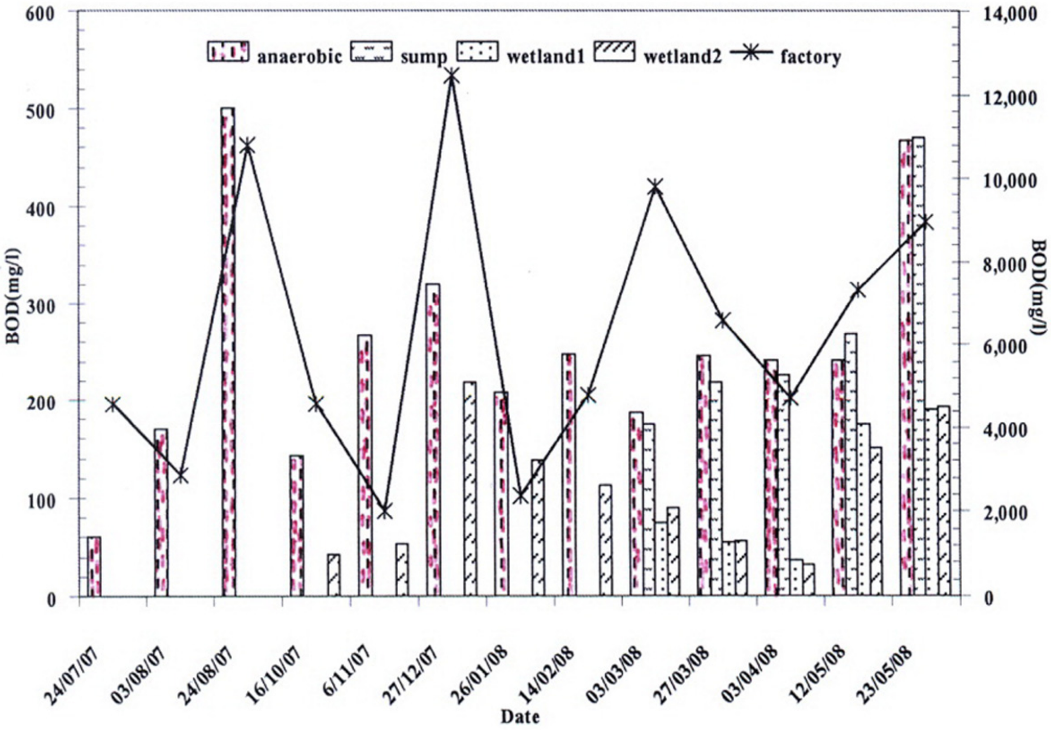

Figure 3. BOD in the raw wastewater and the effluent of each unit.

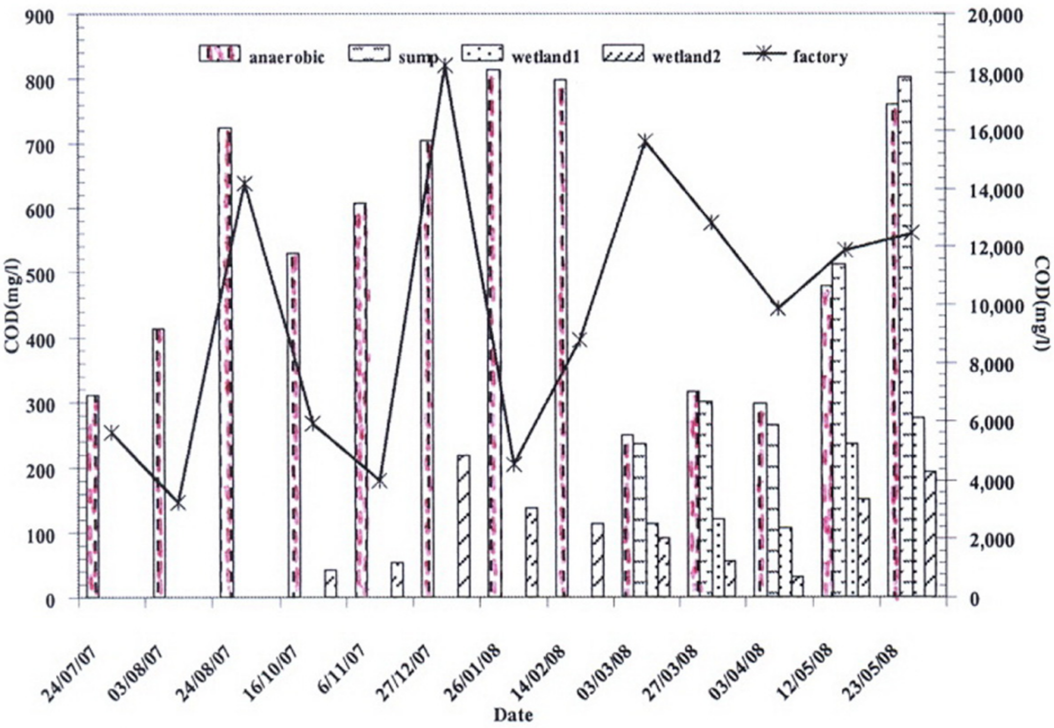

Figure 4. COD in the raw wastewater and the effluent of each unit.

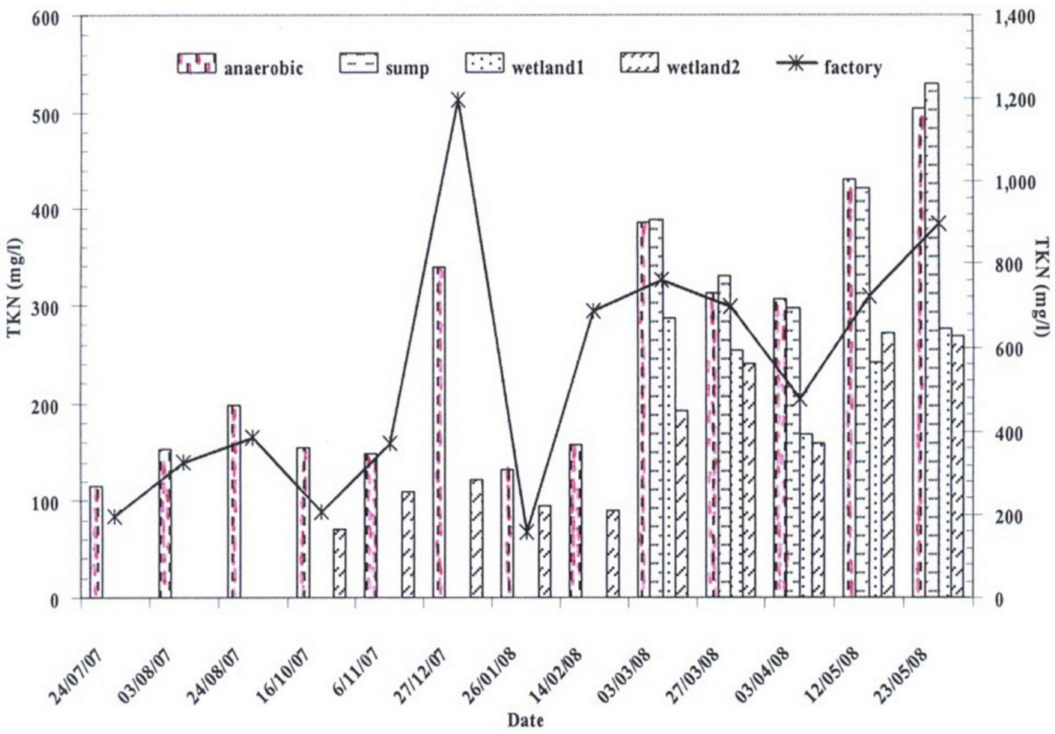

Figure 5. TKN in the raw wastewater and the effluent of each unit.

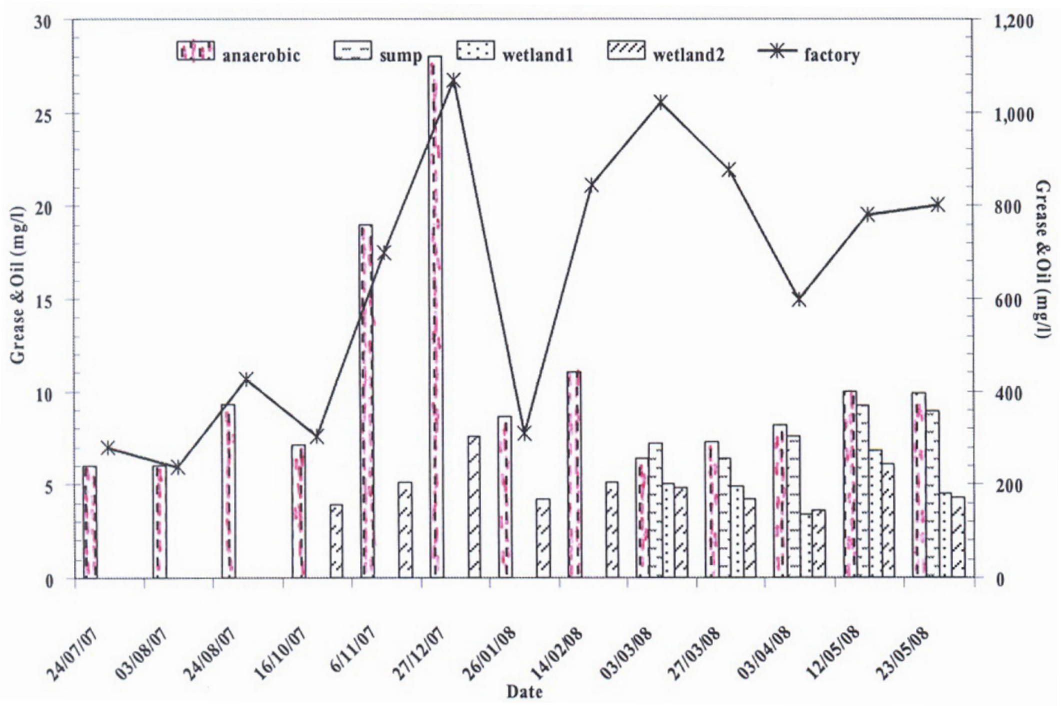

Figure 6. Grease and oil in the raw wastewater and the effluent of each unit.

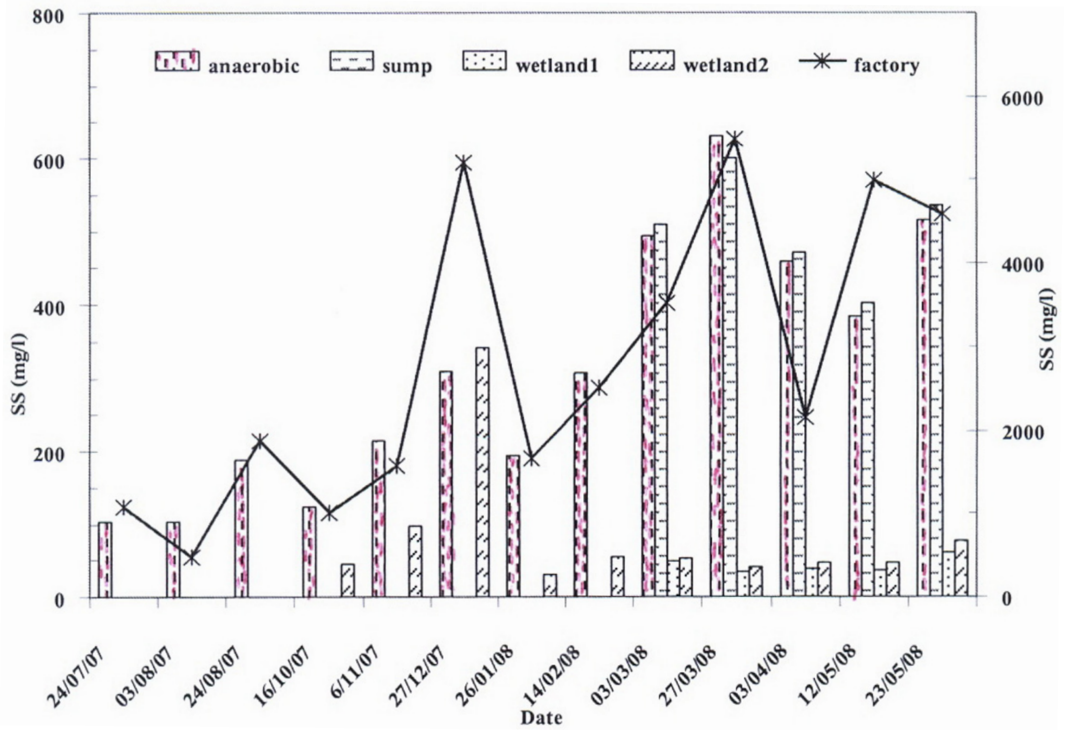

Figure 7. SS in the raw wastewater and the effluent of each unit.

5. ACKNOWLEDGEMENTS

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