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PRE-ENGINEERED (PACKAGE/AND OR ON-SITE) WASTEWATER TREATMENT PLANTS

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Abstract

Package plants are getting more and more popularity not only in drinking water treatment, but also in wastewater treatment. There are some proccesses used to design such kind of facilities. They are extended aeration, contact stabilization, SBR, RBC, oxidation ditch, BMR, physico-chemical treatment etc. In this report two options for pre-ingineered wastewater treatment plant were studied. It was revealed that plant based on principle of Japanese Jokaso using contact stabilization by biological submerged anaerobic and aerobic filters was well suited for on-site treatment of hospital or similar wastewaters.Although relatively high cost of investment, MBR is another promissing option with the best effluent's quality, that can be reused to reduce the treatment cost.

1. Introduction

In wastewater management strategy there are 2 approaches for treatment: centralized or decentralized one. Decentralized/or on-site treatment plants may be produced as concrete constructions or in the form of package/or pre-ingineered/or pre-manufactured plants, they are now commercially available. In the world market although they have capacity up to 3,800 m^3/d., but they are used most commonly in the range from 38 to 950 m^3/d. [1]. The option of decentralized treatment approach has proven favourite over centralized one. Package plants are more economical in term of conduit system, that in centralize scheme may cost as much as about 70% of total investment, besides they save much time for construction, therefore less labour cost; they are best option for removed areas, especially for retrofitting purpose in subjects that are in operation, such as hospitals, hotels, resorts etc. In Vietnam now package plants are also available, for example, CTC proposed V69, TN2000 modular wastewater treatment plants sized of standard steel containners with capacity from 100 to 1000 m^3/d or higher [2], Hanoi Civil Eng. Univ. CEETIA developed BAST, and BASTAF on-site treatment systems using multi-stage anaerobic treatment in concrete constructions [3]. For designing these plants usually biological processes such as extended aeration, contact stabilization, SBR, RBC [4], and recently added oxidation ditch, BMR [5], and also physico-chemical treatment are applied. In this paper some results of application of contact stabilization, and MBR were presented, and some erroneous conclusions in designing and operation of such facilities were also discussed.

2. Experimental part

Contact Stabilization Process.

This process is most applied for on-site treatment in Japan, where treatment of human excreta and gray water is performed chiefly through 3 systems: (1) *Jokaso* – akind of on-site treatment, (2) sewage system – a centralized treatment plant, and (3) human excreta treatment facilities that applied for night soil collected and delivered by vacuum cars from *Jokaso* and other vault toilets [4]. In first applied design, around 1921, Japanese *Jokaso* looked like a combination of septic tank and trickling filter, now it is a combination of different processes, but most popular is contact stabilization one [4]. In contact chambers different kinds of biomass carrying (filtering) materials of versatile configurations are used. They mostly made of plastic or polymeric fibers, configuration may be modules or random fill. In term of the kind of raw wastewater they were divided into simple and combined *Jokaso*. Simple *Jokaso* was designed for toilet flush only, therefore, loadings for calculation are just: volume (L/pe.d) = 50, BOD_5 (g/pe.d) = 12, SS (g/pe.d) = 22, T-N (g/pe.d) = 6. Meanwhile, combined Jokaso receive also grey water, then loadings for calculation are: volume (L/pe.d) = 200, BOD_5 (g/pe.d) = 40, SS (g/pe.d) = 40, T-N(g/pe.d) =10.

For small scale denitrification design a small scale combined *Jokaso* usually has 4 units (Fig.1), which are built in one 4/or 6-chambers pre-manufactured glass fiber reinforced plastic (FRP) tank (Fig.2). In this scheme, designing parameters are based on number of served residents or population equivalent (pe), n. For example, for n = 31 ~ 50, V_1 (volume in m^3 of 1st contact tank) = 5 + (n – 10)*0.3; V_2 (m^3 of 2nd contact aeration tank) = 3 + (n – 10)*0.26, V_3 (m^3 of 3rd and 4th sedimentation & disinfection) = 0.7 + (n – 10)*0.04 [4].

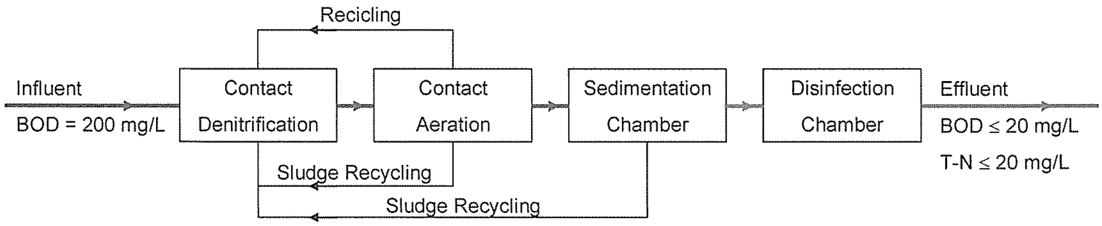

Figure 1. Flow scheme of a small-scale combined Jokaso

Our design was based on [4] with number pe, n = 40, the tank was made of FRP, filtering material was from China. Total volume $V_1 + V_2 + V_3 = 5\ m^3$. Total tank sizes are 2.5(L)*1.5(B)*1.6(H) m^3. Total material used = 1,4 m^3. Other facilities were air pump (10 m^3/h) and tube 4 0.5-meter fine diffusers, sludge recycling pummp, chlorine dosing device. Filtering material configuration was random fill with plastic skeletal balls (Fig.2). Raw wastewater was a combined wastewater from concrete septic tank and from washing facilities at MEDLATEC- a biomedical analysis center in Hanoi.

Treatment efficiency of the system was evaluated through the graphs of changes of COD, $N\text{-}NH_4^+$ along the system during running time.

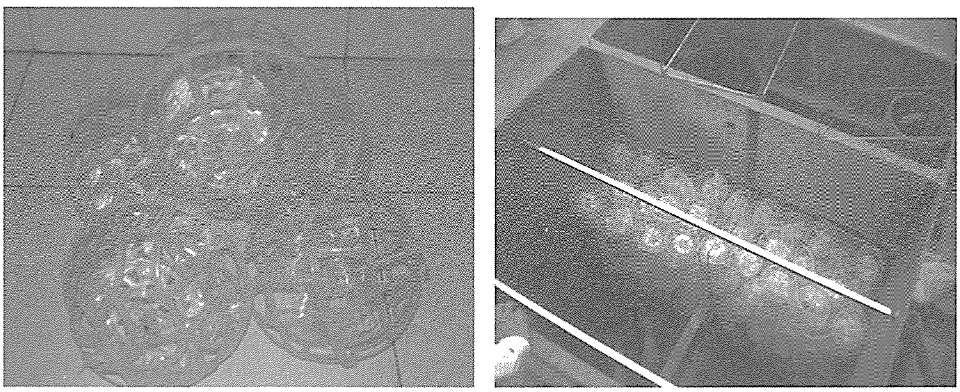

Figure 2. Plastic ball (left) and random fill (right)

Biomembrane Reactor (MBR).

MBR was the last stage of development of the activated sludge (AS) process with replacement of three last principal units just by submerged type of membranes, usuallly MF ones (Figure 3).

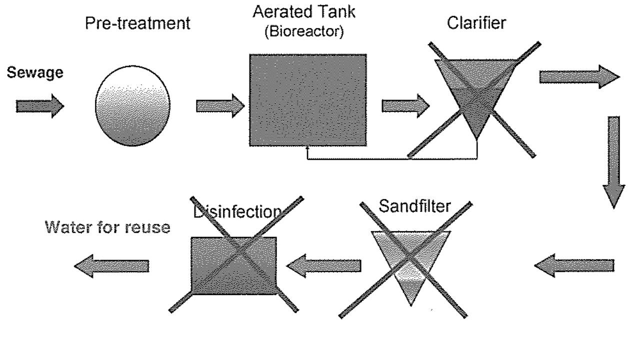

Figure 3. Comparison of activated sludge with MBR

The principal scheme of MBR is as follow (Figure 4).

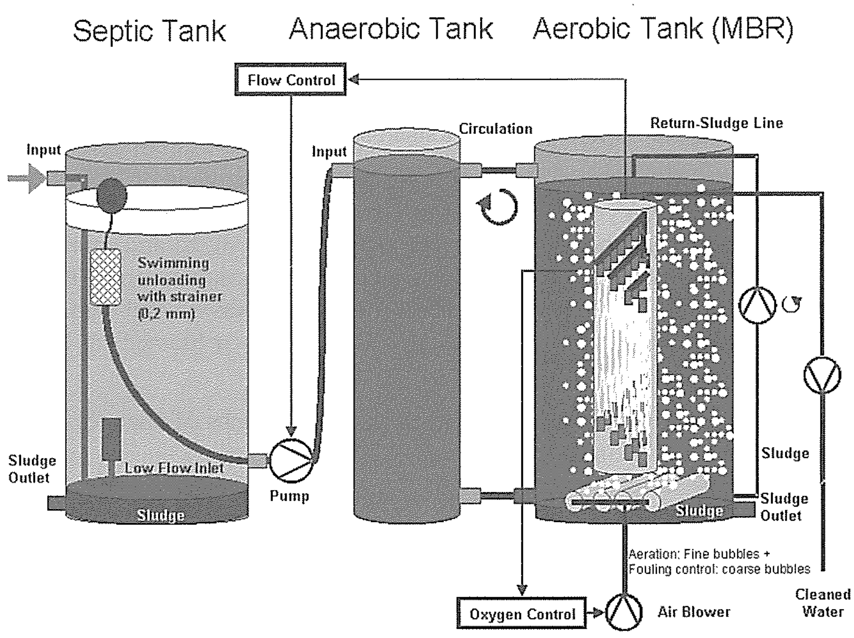

Figure 4. Scheme of the MBR pilot capacity of 12 m^3/d at VIGLAFICO, Ha Tay Province

The MBR pilot plant was designed for C and N removal. The first tank was a septic tank for collecting and pre-treating the municipal wastewater particularly for equalisation, its volume was 2 m^3. The reator was divided into separete anoxic (working V = 2.65 m^3 for denitrification) and oxic (working V = 5.30 m^3 for oxidation of organics and nitrification) tanks. The main part consisted of a filtration modul representing an submerged membrane system and the respective systems engineering (pumps, controlling devices etc.). The mixed liquor was pumped by a recirculation pump from the nitrification to the denitrification stage. In the overflow, the activated sludge was re-routed to the nitrification stage where the membrane module was installed. The aeration for the activated sludge was performed by fine air bubbles and the fouling of the membranes was controlled by back-flushing and pulsed aeration with coarse bubbles (Fig.4) [6]. It was designed to examine the advantages of the process for municipal wastewater treatment with water reuse in long-term operation [7]. The plant was fitted with hollow-fibre MF membranes developed and produced by the Czech company, Eidos Ltd., which uses a special stretching method [8]. In experiments, depending on experimet purpose, 64/or 32 bundles of membranes with a total membrane area of 51.2/or 25.6 m^2.

Analytical and evaluation methods.

COD, SS, N-compounds concentrations, total coliforms count were analysed according to standard methods; VSS was determined by weighing method and also calculated by deviding mixed liquor solid COD values by 1.42. Treatment efficiency was evaluated via appropriate graphs.

3. Results and discussion

Contact Stabilization (CS)

CS was discussed on the COD and $N\text{-}NH_4^+$ removal efficiency after starting-up.

3.1.1. COD Removal

After 2 months from starting reactor began to give fair stable results. Results of COD along the run were presented in Fig.5 below.

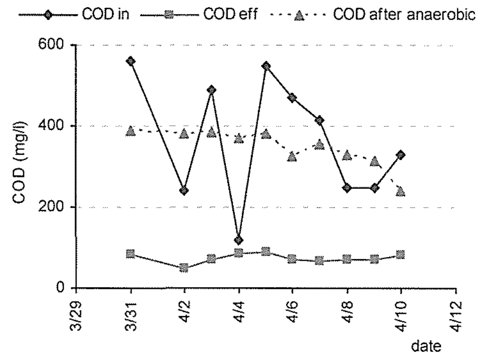

Figure 5. COD changes along the reactor and the running time

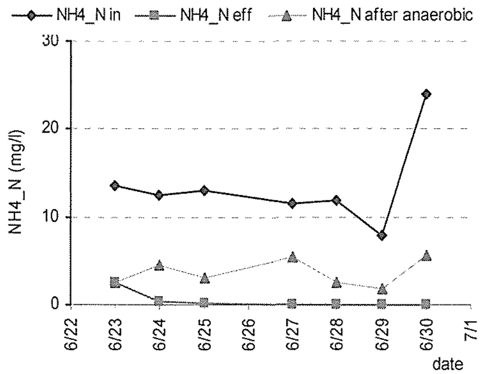

Figure 6. $N\text{-}NH_4^+$ changes along the reactor and the running time

Data showed that influent's COD varied significantly, as low as more than 100 to as high as more than 500 mg/L. After anaerobic chamber COD values were more smooth, and varied between 250 – 400 mg/L, but effluent's COD values were always less than 100 with average value of around 60 mg/L. This values fully met VN standard 5945-2005 for industrial effluent.

3.1.2. Ammonia-nitrogen (NH_4^+-N) removal

The behavior of CS regarding to nitrification was similar to COD removal, data were given in Fig.6.

Because the coming combined wastewater contained a lot of washing wastewater $N\text{-}NH_4^+$ values were relatively low, but after first anaerobic chamber they got values of 10 – 15 mg N/L, that closed to domestic wastewater. At the output effluent had very low $N\text{-}NH_4^+$ concentrations, usually less than 1 mg N/L, that meaned that almost all N species were oxidized into N-nitrate. For denitrification, the next experiments on recycling oxidized wastewater to the first chambers are planned for the next step. Results showed that it is possible to combine all 4 major steps of CS process into one compact tank, that allows to make process to be pre-ingineered like Japanese *Jokaso*. In this process the configuration of the biomass carrying material must be important parameter.

MBR

3.2.1. *COD removal*

COD removal capacity was evaluated through relationship between COD loading (kg COD/m^3.d) and COD removal rate (kg COD/m^3.d) (Fig7.).

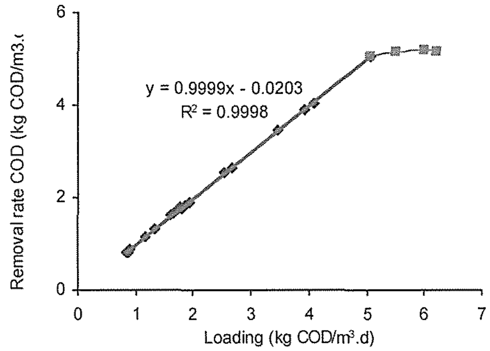

Figure 7. Relationship between COD loadings & COD removal rates

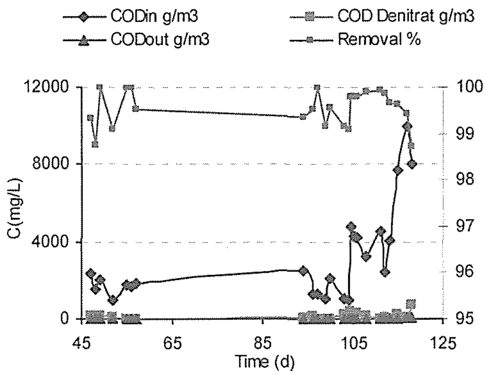

Figure 8. COD data and COD removal (%) in the last three months

Fig.7 showed that when COD loadings increased upto 5 (kg/m^3.d.) one can get nearly 100% removal, accordingly effluent's COD values were as low as 20 – 30 mg/L (Fig.8), that closed to that of natural water. At values of COD loadings of more than 5 (kg/m^3.d.) COD removal rate began to get stable value of about 5 and reduced, that mean 5 (kg COD/m^3.d.) is the maximum possible value of the system, then effluent's COD increased significantly.

3.2.2. *Total N (TN) removal*

The same behaviour was observed in TN removal study. At loadings less than 110 (g N/m^3.d.) one can find that removal rate increased linearly with TN-loadings (Fig.9), meanwhile, TN concentrations was as low as less than 1 (g N/m^3) (Fig.10).

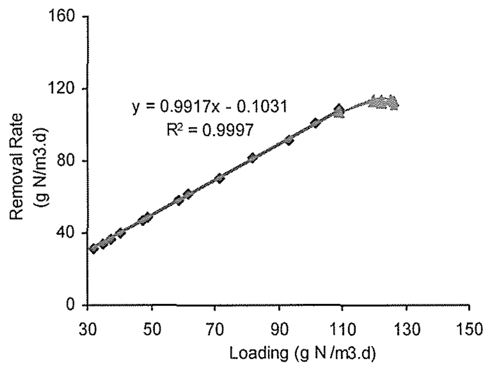

Figure 9. Relationship between TN loadings & COD removal rates

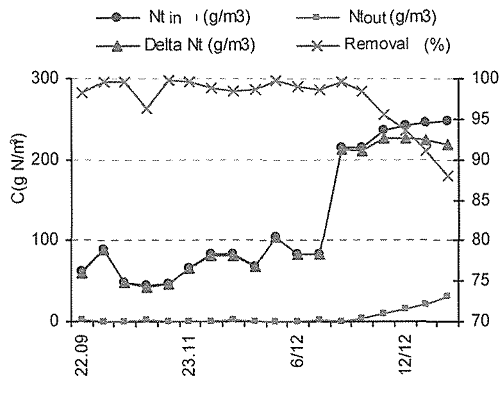

Figure 10. TN data and TN removal (%) in the last three months

3.2.3. *Coliform and Turbidity*

Results of turbidity measurement and coliforms counts (MPN/100 mL) were presented in Fig. 11, 12. Effluent's turbidity was stable, and always had excellent values of less than 4 NTU, coliforms were just a few, much lower US standard value of 20 for the best reused water for irrigation, and met EU demand for swiming pool water quality.

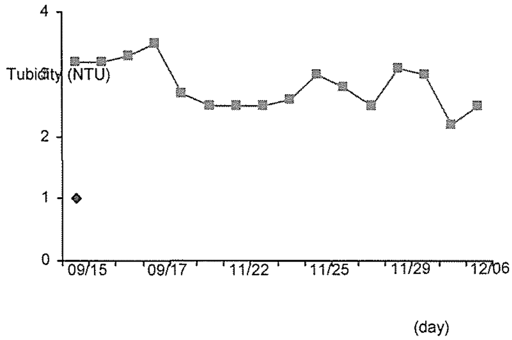

Figure 11. Effluent's turbidity in the last months

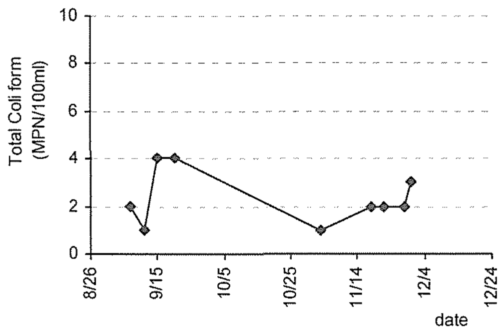

Figure 12. Coliforms count in the last months

An one year pilot study revealed that MBR had numerous advantages over conventional AS. They are: (1) best, and stable effluent quality, that allow to reuse treated water for any irrigation, cleaning purposes; (2) high treatment rate, that resuts in compact design, very low space required, that means that MBR is easily to be inserted into in use new high standard apartment complexes, hotels, resorts etc.; (3) long sludge age leads to deeper treatment and produces very little sludge, therefore less cost for sludge handling. The disadvantage includes: (1) relatively high investment, but this may be compensated by better effluent quality and the cost of water reuse; (2) dependence on foreign membrane supplyers; (3) strict operation procedure, especially membrane maintenance.

4. Conclusion

Two options for pre-ingineered wastewater treatment plant were studied. It was revealed that plant based on principle of Japanese *Jokaso* using contact stabilization by biological submerged anaerobic and aerobic filters was well suited for on-site treatment of hospital or similar wastewaters.

Although relatively high cost of investment, MBR is another promissing option with the best effluent quality, that can be reuse to reduce the treatment cost.

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