香港特別行政區政府渠務署
Drainage Services Department
Government of the Hong Kong SAR

RESEARCH & DEVELOPMENT REPORT NO. RD 2071

Pilot Trial of Membrane Enhanced Primary Treatment (MEPT) Process

(Final Report)

Research and Development Section
Electrical & Mechanical Projects Division
Drainage Services Department

June 2013

Final Report endorsed by R&D Steering Committee Meeting No. 2-2013 (E&M Part) on 28 May 2013.

Minor Consultancy Agreement No. DEMP 10/10

Pilot Plant Trial of Membrane Enhanced Primary Treatment (MEPT) Process at Kwai Chung Industrial Wastewater Sewage Pumping Station

FINAL REPORT

Submitted by

The Hong Kong University of Science and Technology R and D Corporation

Clear Water Bay, Kowloon, Hong Kong

June 2013

Executive Summary

MEPT is abbreviated from Membrane Enhanced Primary Treatment, which is a technology process, property of the Hong Kong University of Science and Technology (HKUST) and which has been developed by Professor Guang-Hao Chen of HKUST. The MEPT process integrates an aerobic macro-filtration, membrane bioreactor (MfMBR) with average pore size of 55 μm, and an anaerobic sludge hydrolysis reactor into a single unit, namely the Oxic-Settling-Anaerobic (OSA) tank. The OSA process is a novel concept that has been developed by Professor Chen for achieving 40% sludge minimization in secondary treatment works.

This minor consultancy project aimed at evaluating the performance and the effluent quality of the MEPT process for potential application in retrofit or upgrade of existing Chemically Enhanced Primary Treatment (CEPT) sewage treatment works towards secondary treatment, with a total Hydraulic Retention Time (HRT) of 4 hrs.

A MEPT pilot trial with an inflow rate of 10 m^3/day was conducted, at Kwai Chung Industrial Wastewater Pumping Station (KCIWPS), from 21 March 2011 to 25 September 2012, to examine the process performance, identify the key process control parameters, establish the process operation procedures, and obtain pertinent engineering data for larger scale demonstration in the future. The main tasks and results are outlined as follow:

Upon completion of the plant design, construction and installation, it was commissioned with 10 m^3/day of 2-mm fine-screened wastewater. The trial was divided into two phases: Phase I was to operate the MEPT pilot plant steadily with a permeate flux $\geq 11\ m^3/m^2\cdot$day, under a constant mixed liquor suspended solids (MLSS) of approximately 3500 mg/L; and Phase II was then to operate the plant under an optimum recirculation flow rate aiming to achieve 50% total nitrogen (TN) removal. Throughout the experimental trial, the sample analysis and on-site measurements focused on suspended solids (SS), turbidity, chemical oxygen demand (COD) (including total (TCOD) and soluble (SCOD)), 5-day biochemical oxygen demand (BOD_5), ammonia (NH_3-N), Total Kjeldahl Nitrogen (TKN), Oxidized Nitrogen (NO_X^--N) and TN. The Operation and control parameters, such as the plant influent flow rate, the recirculation ratio between the MfMBR and the OSA tank, and the permeate flux were mainly evaluated. Optimization of the process was also conducted subsequently to provide pertinent recommendations for application.

The MEPT pilot plant was operated for more than 150 days (i.e. two and a half months in Phase I and two and a half months in Phase II) during which large fluctuations in the influent quality were frequently observed. The average membrane flux of MEPT pilot plant was kept at 11.76 $m^3/m^2\cdot$day, which is much greater than that of the conventional

MF/UF-MBR (up to 1 $m^3/m^2 \cdot d$). Such a higher permeate flux was successfully maintained, while also keeping an acceptable effluent quality. The air-to-water ratio in the MEPT pilot plant was only 15 to 20 L air/ L water but was appropriate for creating an effective shear force on the membrane surface for fouling control. This air-to-water ratio is much lower than that of conventional MBRs.

Despite the largely varying influent quality with substantial amount of inorganic content, for instance, the TSS varied from 1 to 400 mg/L in Phase I, with the TSS in the influent increasing to 1000 mg/L. Also, the performance of the pilot plant remained stable, with the effluent quality meeting the secondary discharge standards. Such a high TSS did not affect the effluent quality, though it led to the replacement of part of the membrane modules.

The results of the performance of the MEPT pilot plant are summarized.

The mean effluent concentrations of the MEPT plant in Phase I were 28.8 mg/L of TSS, 54.1 mg/L of SCOD, 86.0 mg/L of TCOD, 4.6 mg/L of BOD_5, 1.38 mg/L of NH_3-N, and 20.2 mg/L of TN, which correspond to the average removal efficiencies of 94.1, 80.3, 83.1, 98.2, 95.3, and 63.3% for TSS, SCOD, TCOD, BOD_5, NH_3-N and TN, respectively. The mean effluent concentrations of the MEPT process in Phase II were 16.6 mg/L of TSS, 54.9 mg/L of SCOD, 75.7 mg/L of TCOD, 2.6 mg/L of BOD_5, 1.46 mg/L of ammonia-N, and 21.4 mg/L of TN, corresponding to the average removal efficiencies of 96.7, 71.7, 80.9, 98.7, 95.1, and 52.5% for TSS, SCOD, TCOD, BOD_5, ammonia-N and TN, respectively, under the recirculation ratio of 1.2. The effluent concentrations of the MEPT pilot plant indicate compliance with the discharge standards of 30 mgTSS/L, 20 mgBOD_5/L , 80 mgCOD/L, 10 mgNH_3-N, and 50 mgTN/L for small scale treatment plants.

No sludge withdrawal was done during the stable operations of both Phases I and II, with the MLSS concentration in the plant showing insignificant change. This indicated that the OSA tank worked very well on sludge minimization, which happened through sludge hydrolysis that produced sufficient internal carbon source for effective denitrification. Specifically, the average MLSS concentration in Phase I was 3214 mg/L with 17.8-day SRT, while that in Phase II was 2247 mg/L with 22.6-day SRT. The observed overall sludge yield of the plant (including the solids loss via the effluent) was determined to be lower than 0.1 gSS/gCOD, which is much lower than that of conventional A/O process (i.e. 0.35 gSS/gCOD when the SRT is 25 days).

In terms of ammonia removal through nitrification, the MEPT process performed very well. It is noted that the high TN removal efficiency in Phase I was mainly due to the high nitrate concentration in the influent. In addition, the effective sludge hydrolysis in the OSA tank also contributed to the efficient denitrification. The optimal recirculation ratio between the MfMBR and OSA tank, for both the high TN removal efficiency and maintenance of the partially anaerobic condition in the OSA tank, was determined to be 1.2. The control of DO concentrations in both the MfMBR and OSA tank was found to be important for maintaining a partially anaerobic condition in the OSA tank so as to attain good TN removal in the plant. The hydraulic condition in the OSA tank was also observed as an important factor for maintaining this condition. In summary, a relatively low DO concentration in the MfMBR and OSA tank is needed to achieve a high TN removal in the MEPT process.

Due to the large variations of the influent quality and the high contents of inorganic particles in the influent, membrane *fouling* occurred in both phases after two and half months of operation. The characteristics of the influent, scanning electron microscope (SEM) images and the confocal images of the membrane biofilm all indicated that the root cause of membrane fouling was the clogging up of the inner-pores by inorganic particles. Low influent VSS/TSS ratio also supported the high contents of fine sand in the influent. We found that the outer-pore fouling could be easily removed by the routine backwash, but that more than 40% of the inner-pore fouling could not be effectively removed by the routine backwash. Therefore, the effective grit removal in the pre-treatment of this type of wastewater, by the MEPT process, becomes necessary.

A treatment plant based on the MEPT process has the advantages of having a short HRT and small footprint, good effluent quality (effluent TSS less than 30 mg/L, COD less than 60 mg/L, and ammonia less than 5 mg/L), low requirement of influent COD/TN ratio for TN removal, and low construction cost compared with an A/O activated sludge process plant. The MEPT process also requires little or no wasting of activated sludge. Hence, the process shows a great potential for upgrade to secondary treatment level. The MEPT process can be adopted to upgrade the CEPT process in order to provide the biological oxidation and enhance the ammonia and TN removals, simply by doubling the footprint of the CEPT. The MEPT process can also be adopted to upgrade existing conventional activated sludge wastewater treatment processes. For those aerobic processes without denitrification, the MEPT process can be applied to achieve TN removal without the additional footprint requirement. For existing processes with TN removal, the MEPT process can be easily applied with rearrangement of pipeline and membrane modules installation to increase the treatment capacity by up to three times, without additional space requirement.

Following the successful operation of the current MEPT pilot trial, having an inflow rate of 10 m^3/d, to demonstrate the anticipated benefits of the MEPT process, HKUST will conduct a series of optimizations in the MEPT process for both normal municipal and industrial wastewater. The inter-relationship among influent particle size distribution, the suspended activated sludge floc size distribution, optimum membrane pore size, and membrane fouling will be carefully studied in the future. It is expected that the experimental result could be used as guidance for membrane pore size selection according to different influent characteristics. Based on the aforementioned experimental results, the HKUSTRDC's suggestion to the DSD is to conduct a trial of the fully optimized MEPT process in order to obtain adequate information and data for full-scale applications.