

Comparison of Full-Scale a Conventional Activated Sludge Plant and a Ceramic Membrane Bioreactor: Nitrification Efficiency in Domestic Wastewater Treatment Mingled With Industrial Wastewater

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ISKI Ataköy Biological Wastewater Treatment Plant (WWTP) is a biological nutrient removal (BNR) system, consisting of anaerobic, anoxic and oxic zones, with a capacity of 390,000 m³/d. Influent wastewater source is mainly of domestic origin; however there is a considerable amount of industrial wastewater contribution. The plant is divided in three parallel lines consisted of an anaerobic tank and, two cascades with pre-denitrification and internal recirculation.

A pilot scale Moving Bed Ceramic Reactor (MBCR) was installed after the grit-grease chamber and operated for one year (Figure 1, 2). The bioreactor is based on nitrification and denitrification processes with a process capacity of 20 m³/day and a hydraulic capacity of 45 m³/day. Influent wastewater characteristics are given in Table 1. The wastewater passes through 50 mm coarse-screens, 10 mm fine-screens and aerated grit chambers before entering the 3 mm mesh screen. The treatment sequence consisted of three consecutive biological tanks (anoxic and oxic zones), which contains the carrier material for biological growth. The second part of the pilot plant is the lamella separator, where the settled sludge is recycled and wasted and, partially clarified mix-liquor is gravitated to the ceramic membrane filtration unit. The next part of this container is the backflush unit. Permeate is stored in this tank and used as pressure controlled backflush water in order to prevent membrane fouling and maintain a stable operation. In addition, chemical cleaning (sodium hypochlorite, citric acid, perchloric acid) is carried out periodically.

The operation strategies aimed to show the maximum biological capacity combined with a high filtration performance. In order to meet these demands, biological degradation had to be considered first. Following the establishment of the biological system and the biological degradation in phase 1, phase 2 was scheduled to focus on the maximum capacity by optimization of the processes. Once the specific biological parameters were determined, the flux increase can be achieved by optimization of the operational mode and adjusting the cleaning strategy (Kramer and Kaplan 2014).

In order to ensure the biological activity and the treatment performance the following parameters were monitored: pH, conductivity, total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen (TN), ammonium, total phosphorus and fecal coliform. The effect of industrial wastewater on the biological system was detected by following parameters: Al, Cd, Co, Cr, Cu, Fe, Hg, Ni, Pb, Zn, SO₄²⁻, CN⁻, detergents and phenol.

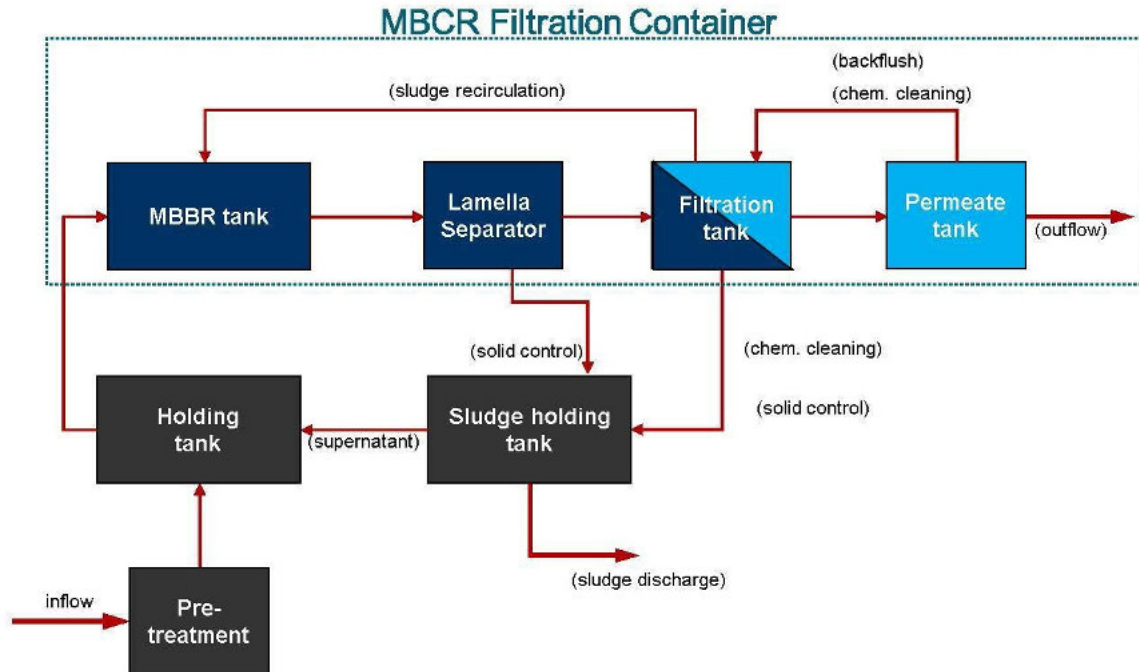


Figure1: Process Diagram (Kramer and Kaplan 2014).



Figure 2: Illustrational mounting of pilot plant on Ataköy WWTP

Table1: Pilot plant influent wastewater characteristics.

Parameter	pH	TSS	COD	BOD ₅	TN	NH ₄ -N	Conductivity
		mg/L	mg/L	mg/L	mg/L	mg/L	μS/cm
Minimum	6.44	92	142	160	30.88	14.60	673
Maximum	8.74	1730	1167	660	126.00	95.37	8990
Average	7.72	439	617	369	68.41	44.78	1685

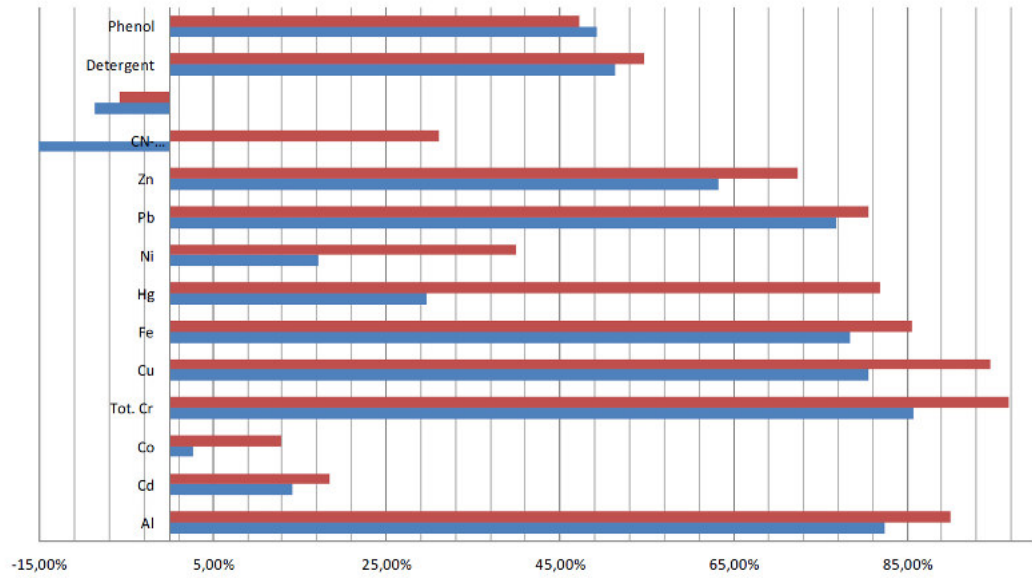
On-line operational control tools of the pilot plant were; pressure indicator, oxygen meter, flow meter, hydrostatic level sensor, flow controlled blower, temperature sensor, ammonium- and nitrate analyzer.

The average treatment results are: TSS_{in} 442 mg/L: >> TSS_{out} < 5 mg/L, BOD_{5in} 371 mg/L: >> BOD_{5out} < 4 mg/L, COD_{in} 620 mg/L: >> COD_{out} < 36 mg/L, TN_{in} 69,1 mg/L: >> TN_{out} around 10 mg/L, flux: about 30 L/m²/h, power: about 2,39 - 1,91 kWh/m³ of feed water, sludge volume: 3,26 m³/d. Heavy metal and Total Cyanide analyses have been conducted in Ataköy WWTP inlet, Pilot Plant effluent and Ataköy WWTP effluent. Ataköy Plant does not have any significant problem with heavy metals but when compared to the performance of MBCR unit, the heavy metal removal was better than the conventional activated sludge process of Ataköy WWTP as shown in Figure 3. Ceramic membranes had not encounter any irreversible blockage or reduction on flux (Figure 4).

Domestic wastewaters mingled with industrial streams contain various chemical substances, most of which are difficult to decompose with activated sludge. However, microorganisms can influence metals' mobility in the environment by modifying their chemical and/or physical characteristics (Eccles 1999). Slow-growing nitrification bacteria are more sensitive than ordinary heterotrophs, and their growth rate is used to determine the operational strategy of a BNR system. Thus, nitrifiers are known to be more sensitive to toxic chemicals (Tantasut et al.2006). Hence, process selection, configuration and operation strategies directly affect nitrification efficiency and sustainability.

Biofilm systems reported to be 2 to 600 times more resistant to heavy metal stress than free-swimming cells (Tietzel and Parsek 2003). MBR systems can also efficiently remove heavy metals with or without additives (Katsou et al.2011); MBR systems improve the removal efficiency by 10–15% compared to the conventional activated sludge systems (Bolzonella et al.2010). Nitrification performance of the pilot plant was better than the full-scale plant, especially in terms of handling shock industrial contributions. Heavy metal removal efficiency in the pilot plant was 4–52 % higher depending on various metals; the highest removal rate was achieved for mercury (Figure 3). The better elimination of heavy metals in the pilot system reduced biomass inhibition and autotrophic biomass growth maintained efficiently under shock or increased industrial wastewater loads.

Besides the significant distinction in mercury removal, the main difference of two systems was the total cyanide (CN⁻) removal efficiency (Figure 3). Total cyanide removal efficiency in the pilot plant was 31 %, while in the full-scale plant total cyanide accumulated (efficiency: - 32 %). Approximately one thirds of CN⁻ removal was advantageous in terms of nitrification. Attached growth systems are less sensitive to cyanide inputs and carriers were advantageous for nitrification systems subjected to short-term inputs of cyanide (Weon et al. 2004). On the other hand, the membranes were backwashed by sodium hypochlorite (NaOCl) periodically. CN⁻ can be oxidized by NaOCl efficiently under alkaline conditions and fully removed when pH is around 11. Cyanide derivatives like cyanate (CNO⁻) ion can be oxidized by chlorine at neutral pH (Sinbuathong et al.2000). NaOCl backwash could be a reason for partial CN⁻ removal. It was possible to raise pH up to 9 during backwash, which can provide oxidation of cyanide derivatives and reduce total cyanide. Because the recirculation of the system is done from the membrane tank it is possible to dilute influent toxic load. Besides, the chlorine dosing can be increased or adjusted according to nitrification requirements. This is one of the advantages of using ceramic membranes, which are resistant to high chemical dosage or increased backflush.



	Al	Cd	Co	Tot. Cr	Cu	Fe	Hg	Ni	Pb	Zn	CN-Cyanide	SO42-Sulfate	Detergent	Phenol
PILOTREMOVAL	89,99%	18,39%	12,86%	96,67%	94,65%	85,61%	81,88%	39,98%	80,58%	72,34%	31,06%	-5,82%	54,63%	47,22%
ATAKOYREMOVAL	82,47%	14,17%	2,69%	85,73%	80,61%	78,34%	29,54%	17,13%	76,90%	63,21%	-32,08%	-8,67%	51,31%	49,23%

Figure 3: Heavy Metal and Total Cyanide removal efficiencies.

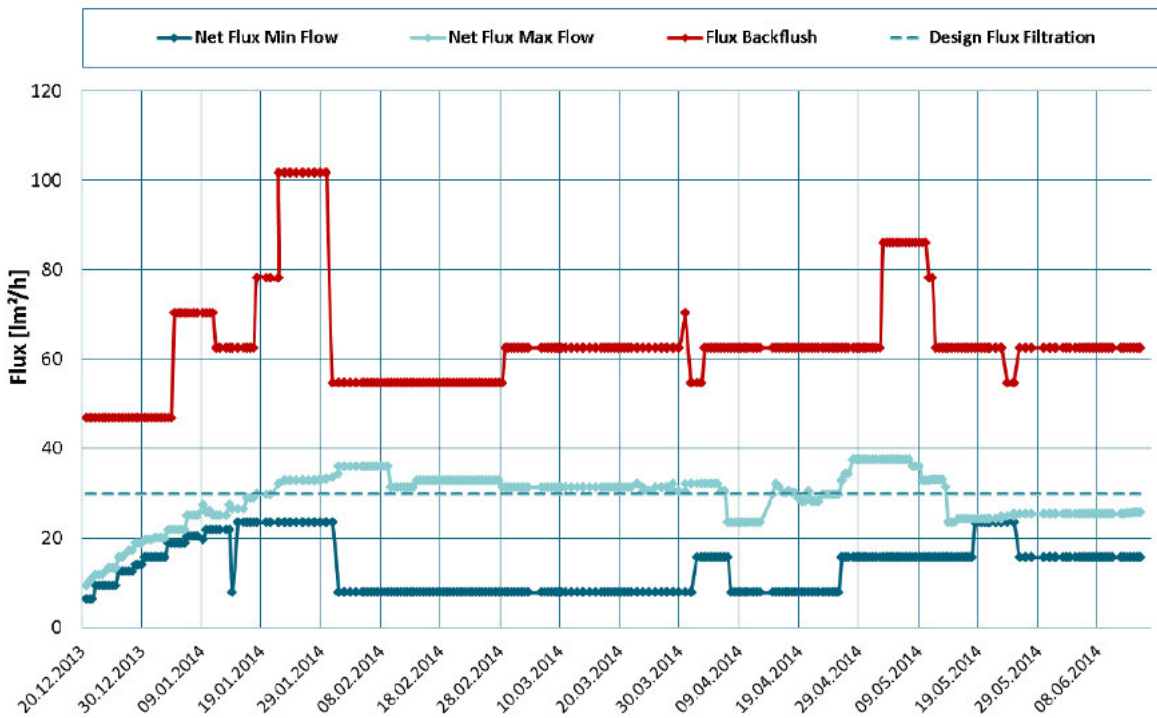


Figure 4: Set flux diagram (Kramer and Kaplan 2014).

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