A case study of challenging pharmaceutical wastewater treatment with MBBR

Keren Nof[1]*, Debora Sela[1], Gali Stamper[1]

[1] Aqwise- Wise Water Technologies Ltd.
* Email: keren@aqwise.com

ABSTRACT

Pharmaceutical wastewater is characterized by high COD content and fluctuations in flow and load depending on the production, making the treatment challenging. This paper describes a case study of the existing Perrigo Yerucham wastewater treatment plant, where the Moving Bed Biological Bioreactor (MBBR) technology was implemented. The data shown includes design parameters, plant configuration, start-up results and operational results over a year.
Throughout this period of time, COD concentrations were effectively reduced and were below discharge regulations even after organic peak loads events, demonstrating that MBBR technology is suitable to treat pharmaceutical wastewater.

KEYWORDS: Industrial wastewater, secondary treatment, MBBR

INTRODUCTION

Treatment of pharmaceutical wastewater is known to be challenging. Pharmaceutical wastewater is usually characterized by high COD concentration and can contain not only easily biodegradable carbon but also high fractions of hardly degradable carbon compounds (Chelliapan and Sallis, 2011). In addition, the composition of the pharmaceutical wastewater may vary and fluctuations in organic load often occur due to batch operation and depending on the manufactured product. Further complications include the presence of biological inhibiting compounds.

Perrigo is a leading global healthcare supplier. Perrigo has a facility in Yerucham, Israel, that is dedicated to the formulation of creams, ointments, gels and pharmaceutical foams (topical formulation) as well as formulation of tablets (enteral formulation). Production activities run from Sunday to Thursday, 5 days per week, 8.5 hours per day, and are stopped during the weekend, from Friday to Saturday. On Fridays, the production lines are cleaned.
Being a global supplier, the production operates in compliance with the current good manufacturing practice (CGMP) guidelines, a regulatory standard enforced by the FDA to ensure pharmaceutical quality. This standard includes, amongst others, maintaining a clean manufacturing area, which implies that complying with the CGMP regulation can result in an increased wastewater output with detergents content.

The wastewater from Perrigo plant used to be treated together with wastewater from a neighboring industry. The only treatment of the wastewater before being discharged to the public sewer was a dissolved air flotation (DAF) unit. In 2014 the two production plants were separated and a new dedicated wastewater treatment plant was required for the Perrigo formulations plant. A decision was made to install a Moving Bed Biological Reactor

(MBBR) system to treat the wastewater. The MBBR technology utilizes free-floating plastic biomass carriers with a high specific surface area of attached biomass (biofilm). The MBBR technology was selected because it can robustly cope with fluctuations in flow and organic load and because the MBBR technology has a short recovery time after toxic events. Other advantages of the MBBR technology are the simplicity of operation and maintenance, the possibility of future expansion of the system by addition of biomass carriers, and small footprint when compared to conventional biological processes.

This paper summarizes the operations of Perrigo Yerucham wastewater treatment plant and describes the initial process design parameters and the plant configuration, the start-up phase and the results from one year of operation. The wastewater from the plant is characterized by high fluctuations in COD concentration and varying flow. Nevertheless, the effluent quality is not affected by these conditions. The experience in Perrigo showed that the MBBR is an adequate and robust technology, which can cope well with the challenges of pharmaceutical wastewater treatment.

DESIGN PARAMETERS AND PLANT CONFIGURATION

The main wastewater parameters that were considered as design basis are summarized in Table 1. The average design wastewater flow is 75 m^3/d, the maximum design COD concentration is 3,600 mg/l after an equalization tank and the maximum design TSS concentration is 100 mg/l. The effluent of the treatment plant is being discharged into the public sewage system with the required COD effluent concentration of 800 mg/l and TSS concentration of 400 mg/l.
Figure 1 shows the plant configuration to achieve the required effluent quality.

Table 1: Design wastewater parameters

Parameter	Unit	Raw wastewater	Effluent requirements
Flow rate	m^3/d	75	
COD total	mg/l	3,600	800
COD total, load	kg/d	270	60
TSS	mg/l	100	400

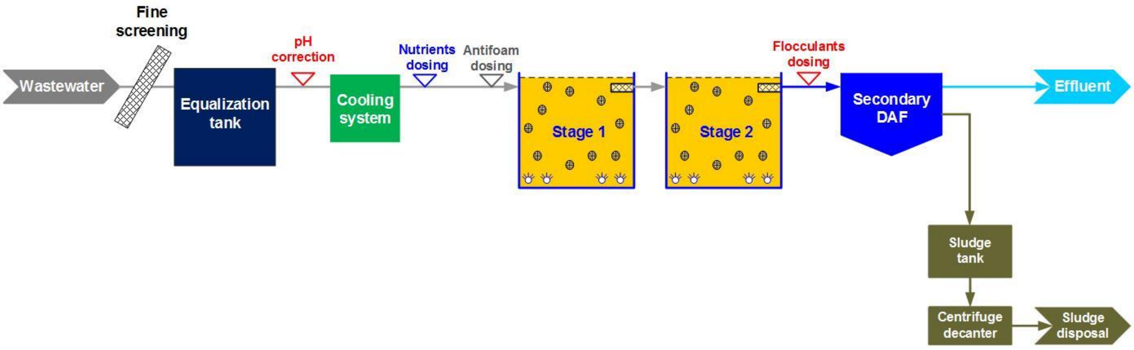

Figure 1: Process flow diagram, Perrigo Yerucham

The wastewater flows after the fine screen to an equalization tank of 27 hours. In addition to the equalization tank, two emergency tanks were installed. pH of the raw wastewater can have a wide range, depending on the produced pharmaceutical and cleaning agents. Therefore, the pH is controlled before the equalization tank. In case of extreme pH values, a part of the wastewater can be diverted into the emergency tanks to avoid extreme pH downstream.

The temperature of the raw wastewater varies between 25 and 50°C. In order to enter the MBBR reactor, the wastewater has to be maintained below 35°C. Therefore, the wastewater flows from the equalization tank to a cooling system that cools down the wastewater if necessary. Since there is a lack of nutrients in the wastewater, Urea and Phosphoric acid are being dosed before entering the MBBR for biological growth.

The biological reactor includes two stages of MBBR for COD removal. The two reactors work in series, each reactor has a 50% carrier fill ratio and the total design HRT is 25.6 hours. An antifoam dosing system is installed to avoid foaming in the reactors. Foaming in the biological reactor can be caused by surfactants in the wastewater. The surfactants in the wastewater originate on one hand from the cleaning agents used to clean the production line between batches. On the other hand it can originate from products that are manufactured in the plant such as shampoo. After the biological reactor a DAF unit is installed for secondary solid liquid separation. Sludge treatment includes a sludge tank and a centrifuge.

Given that the treatment plant is near the production plant, an odor treatment system is installed to avoid odor emissions. The odor treatment system collects air from the equalization and emergency tanks, the biological reactors, the DAF unit, the sludge tank and centrifuge.

STARTUP AND OPERATION RESULTS

Startup

Operation of the Perrigo Yerucham wastewater treatment plant started by the end of December 2014. The site view of the plant is shown in Figure 2.

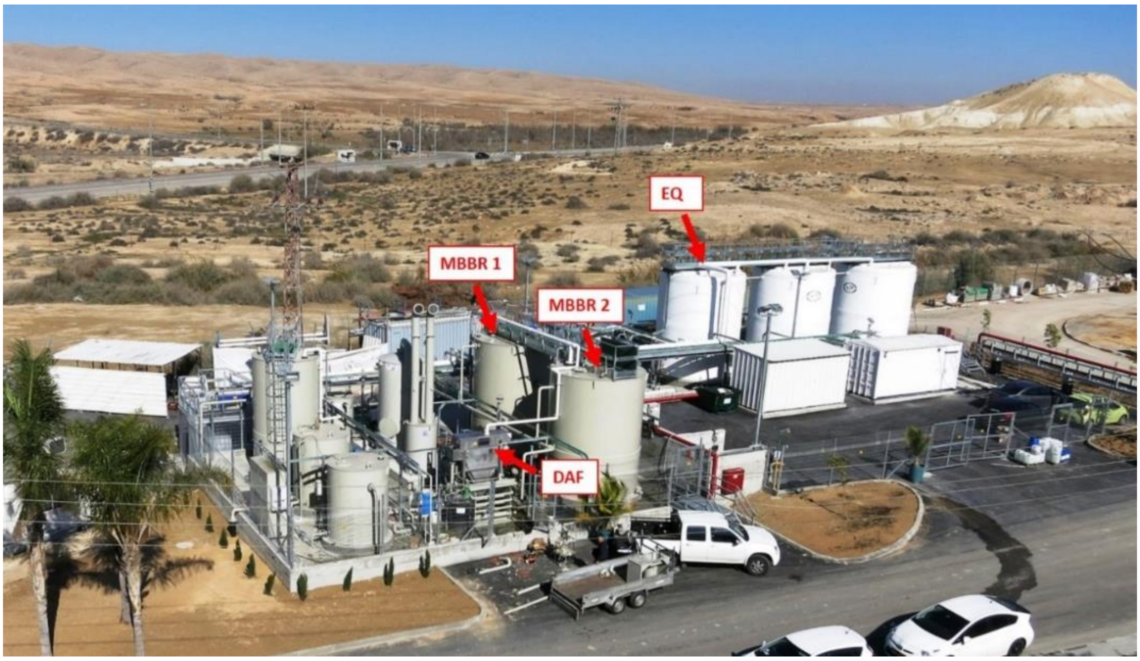

Figure 2: Site view, Perrigo Yerucham

After only three weeks of operation, the system was acclimated and the start-up phase was completed. Table 2 presents inlet and effluent COD concentrations measured during the last two weeks of the start-up. It can be seen that the measured effluent values are within the required effluent quality of 800 mg/l COD.

Table 2: COD inlet and outlet concentration during start-up

Date	COD in (mg/l)	COD out (mg/l)
07 / 1 / 15	1380	590
14 / 1 / 15	1560	800
19 / 1 / 15	1280	370

Biofilm formation

After the start-up was finalized, fully developed biofilm was observed on the carriers. In Figure 3 the carriers from the first and second MBBR reactor are shown. It can be seen that the biofilm on the carriers is thicker in the first reactor than in the second one. The higher the loading rate on the carriers, the more compact the biofilm produced (Ødegaard, 1999). Since most of the organic load is removed in the first MBBR reactor, the second stage is low loaded and only a thin biofilm is developed.

Figure 3: Carriers from MBBR 1 and 2 with biofilm

Operation results

Figure 4 presents the COD inlet and outlet concentration in the course of one year of operation (August 2016 – July 2017). Values are shown in two different locations in the plant. The inlet samples were collected after the equalization tank, before entering the MBBR reactor, and the outlet samples after the secondary DAF. Also shown in the graph are the design inlet quality and the required effluent quality. The required COD effluent quality was achieved during the whole year, except for a few days in September 2016. The incident in September was due to an exceptional peak of inlet COD concentration of 8,570 mg/l, which was 2.38 times the inlet design basis of 3,600 mg/l (Figure 4, circled in red). This high COD value was the result of a one-time cleaning action in the production line. Notably, the results show that the system recovered fast from this extreme event. There were other occasions in which inlet COD concentration exceeded the design basis and in all of those cases the required effluent specifications were still met (Figure 4, circled in green).

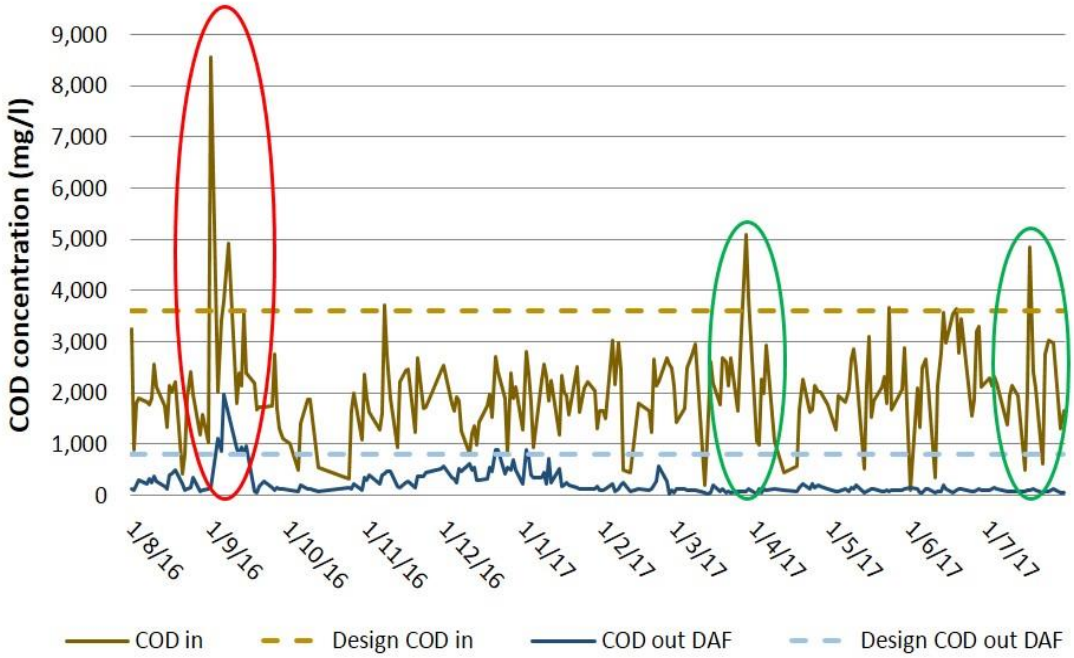

Figure 4: COD inlet/outlet concentration, Sept. 2016 – Aug. 2017

In Figure 5 the TSS concentration during one year of operation is shown. TSS values are shown at inlet to the MBBR, at outlet of the MBBR and at outlet of the DAF.
The TSS inlet concentration varies between 5 and 30 mg/l, which is relatively low compared to the design inlet value of 100 mg/l.
The biomass to be separated after the MBBR, includes the inlet TSS and the surplus biomass as a result of sludge yield. It can be seen that TSS concentration after the MBBR reactor shows an increasing trend around May 2017. An increase in TSS concentration after the MBBR reactor would normally be attributed to either higher TSS concentration in the influent or higher COD load, leading to higher biomass production during the biological process. No increase in inlet TSS nor increase in COD load during this period was observed. A possible explanation could be that the additional TSS concentration is coming from another stream that enters the reactor. One possible stream is the supernatant stream from the centrifuge that is being re-diverted to the MBBR reactor. In cases where the centrifuge does not work properly the supernatants may contain high amount of suspended solids. Another source for the higher TSS could be the washing water from the DAF unit, which also can contain high concentration of suspended solids and is being diverted to the MBBR reactor. Further sampling and measurements are necessary in order to establish the source of the increasing TSS concentrations at outlet of the MBBR reactor.

Although the TSS after the MBBR increased, the required TSS effluent quality is achieved during the whole year.

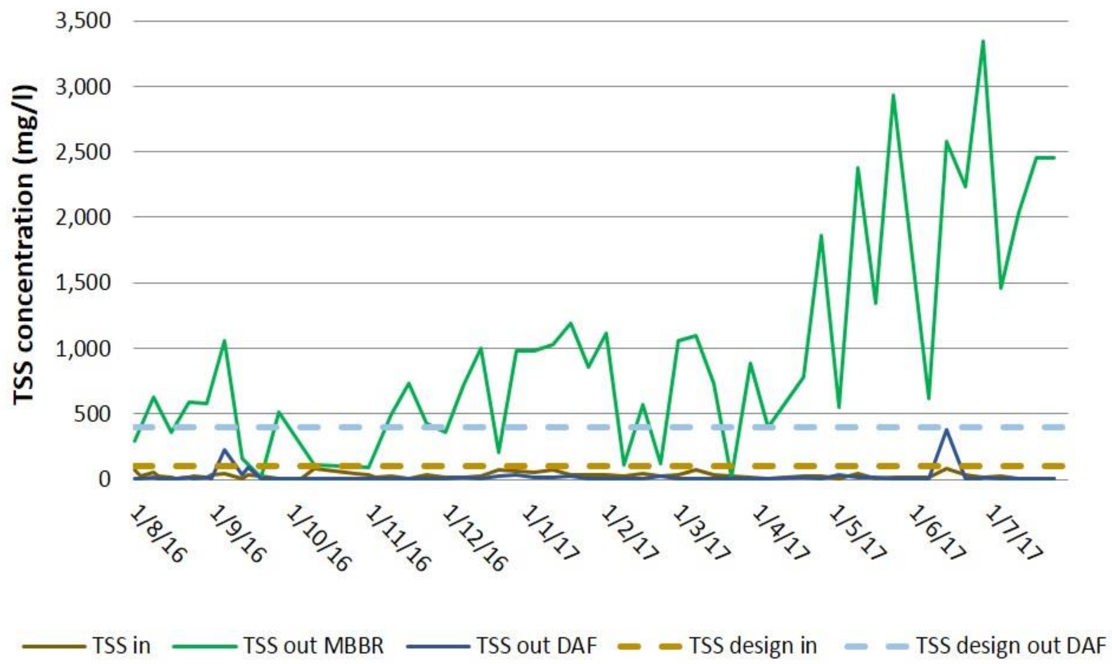

Figure 5: TSS inlet/outlet concentration, Sept. 2016 - Aug. 2017

To provide a better picture of the weekly variation of COD, the daily inlet concentration during one typical month of operation (July 2017) is presented in Figure 6. The figure additionally shows the effluent COD concentration from the MBBR reactor and the secondary DAF as well as the average daily flow.

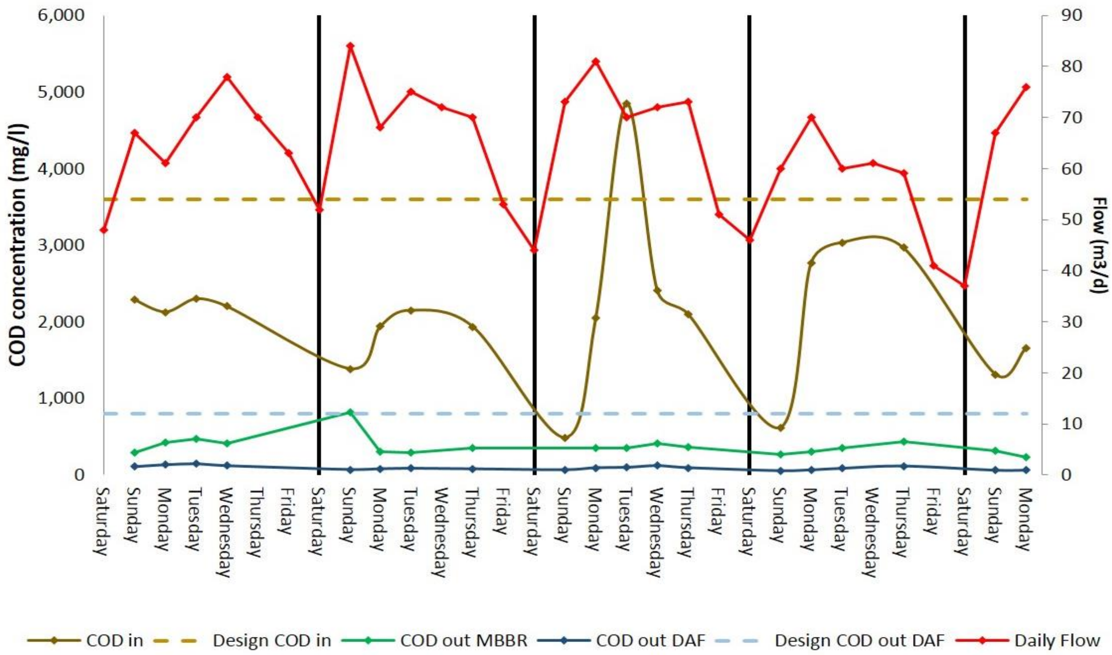

Figure 6: COD inlet/ outlet concentration and daily flow, July 2017

The daily inlet flow to the treatment plant during this period varies between 37 m^3/d and 84 m^3/d. During the week, flow decreases on Fridays and the lowest value is measured on

Saturdays. This correlates with the working regime of the Perrigo manufacturing plant. Since the production is stopped from Fridays to Saturdays, less flow enters the treatment plant during weekends. Yet, flow does not stop completely and it consists of effluent from cleaning processes of the production line and of RO effluent from production.
It can be seen that there are high fluctuations in the COD inlet concentration. The COD inlet concentration varies between 485 mg/l and 4,852 mg/l. The values measured on Sundays are the lowest values during the week and reflect the diluted wastewater concentration after the weekend. Despite the high variation in inlet COD concentration, the daily measured effluent COD values from the MBBR reactor do not show any fluctuations and are consistently within the required effluent concentration.

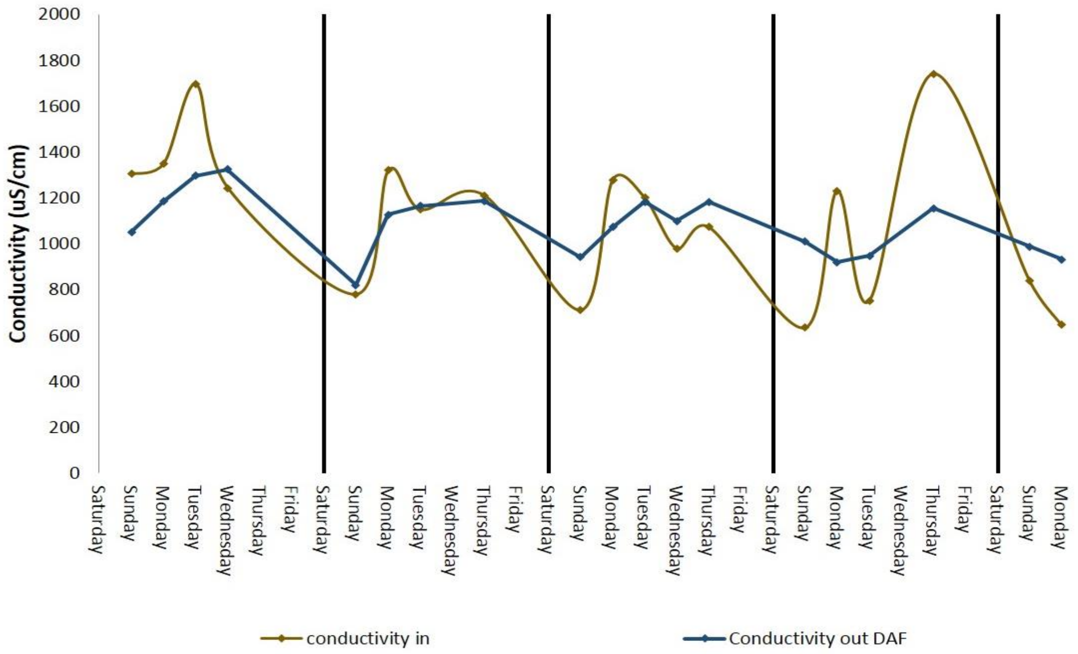

Figure 7: Conductivity inlet/ outlet, July 2017

The wastewater trend during the week is also visible in conductivity values. Figure 7 shows the conductivity at inlet to the reactor and outlet of the DAF during the same month (July 2017). Conductivity varies between 635 and 1,740 µS/cm. It is visible that also the lowest conductivity values are on Sundays. This indicates the dilution of the wastewater during the weekend with cleaning water and RO effluent from the production which contains lower conductivity values than the wastewater. The conductivity values at outlet of the DAF are in the range of the inlet values. Fluctuations in the outlet values are attributed to chemicals dosing during the process such as pH correction and coagulant dosing.

SUMMARY AND CONCLUSIONS

Perrigo facility in Yerucham Israel represents the typical challenges of pharmaceutical wastewater treatment plant including high fluctuations in flow and organic loads.
The data presented on the MBBR system installed in Perrigo's facility shows that the effluent quality of the treated wastewater is within the effluent requirements despite fluctuations in COD concentration and flow.

It has been shown that the MBBR system recovers rapidly after organic peak loads that exceed the design values.
In addition, the MBBR system acclimated quickly after initiation of operation and start-up was finalized after three weeks.
Altogether, these results show that the installed system performed robustly and that the MBBR technology is well suited to cope with the challenges of pharmaceutical wastewater treatment.

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