THE EFFICIENCY OF MUNICIPAL WASTEWATER TREATMENT WITH RECONSTRUCTED ACTIVATED SLUDGE METHOD, THE IMPORTANCE OF TEST PHASE

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Abstract—Centralized wastewater treatment policy is a common challenge in Hungary. With the recent technology improvement of the Debrecen Wastewater Treatment Plant, the original activated sludge function system's maximum load is doubled, making it able to treat the influents of 7 settlements total. The introduced new technical constructions however required strict attention to be successfully implemented into the existing system. Retrofitting the overall processes caused disturbances affecting certain parameters in the biological elimination, thus modifying water quality of the effluent. Our experiments had aimed to control the performance of the plant after the reconstruction during test phase for more than a year period. It has been found that a slight increase of removal efficiency was achieved in the observed parameters of COD, BOD_5, TP, SS, while TN remained in a moderate degree of enhancement. Retention effectiveness has begun to escalate significantly after a year of operation.

Keywords: activated sludge, efficiency trend, test phase, chemical parameters

INTRODUCTION

Centralization in the modern civilization is the possibility of development. Wastewater treatment plants (WWTP) tend to get larger along with the ever growing settlements with their services. It is sometimes the one and only solution to satisfy the demand of highly populated area, and certainly it is absolutely the most applied way to treat wastewater [1, 2]. After joining the EU, small scale treatment plants have to perform higher quality of outflow treated water. The reasons behind these can be connected mainly changing economic considerations, or shifting technical implementations [3]. Nevertheless, centralized systems are good enough option in many cases and - most importantly - they already exist. Maintenance and performance optimization is adequate in terms of available constant efforts what they require. Debrecen is the capital of Hajdú Bihar County, with a population of around 200 thousand which is the second most populated city of Hungary. Located in the North Great-Alföld with elevation of 119,6 m a.s.l., the WWTP of Debrecen is operated by the Debrecen Waterworks. Starting with the 80's it has evolved from a labyrinth of oxidization ponds (constructed wetland) into multi-structured plant throughout the years. Expanding the already functioning activated sludge technology was self-evident. Evaluations have concluded that the conventional activated sludge technology is still efficient and give stable operation.

The pollutant removal efficiency is the point of expressing the capability of WWTP to prevent pollutants to inflow into the water recipient. Actually, pollutants are not literally removed, but their path is altered so that they can cause less danger to the environment, moreover to recycle all those materials e.g., nutrients contained in waste sewage can be used as fertilizers in agriculture [4, 5].

With the currently accepted operating status the WWTP is licensed to treat the wastewater of Józsa, Mikepércs, Sáránd, Hajdúsámson, Ebes and Debrecen either, hence the radical reconstruction development. Mechanical treatment received an additional fine screen and a modified sand filter. The biological treatment section existing constructions were reconfigured and a new treatment line with the similar size of the original was constructed. Excess sludge treatment received an additional sludge digester tower with complementary facilities. As a result, the effective capacity of the plant is doubled, making it capable for receiving an average of 2500 m^3 sewage per hour, with a total 60 thousand m^3 per day capacity. However, construction plans mainly focus on raising the overall capacity, providing a long term of usability for around 4-5 years, in some cases more. Predicting future dynamics in a wastewater system demands a long-term vision of water management in the given area. The role of this attitude is occasionally unknown among practitioners and decision makers. Upgrading or designing structures mostly based on assumption that certain future changes can be really true. But, these forecasts usually fail to meet their purpose, therefore their existence are highly questionable. Technical and global evolution outperforms the readily available knowledge of important factors. Not to mention the whole planning phase and then the long operational life of these wastewater compositions [6, 7]. Reasonably, a miscalculated forecast might easily lead to an over- or under-loaded plant. Heavy rainfall events or single accidents by industrial wastewater may cause overflow phenomena and contamination; also initial low hydraulic loading rates suppress microbiological processes.

Meanwhile, engineering planning have naturally includes the dimension of the implementing process; the constructions begin, and due to strict deadlines are forced to be finished in time. As new structures are connected, others are disconnected if required, the operating staff pressed to keep the treatment and effluent water quality under control. Under these circumstances we must accept that not only the technology ‘‘hardware’’ is important but the operating ‘‘software’’ is as well [8]. The goal of our experiment and data collection was to find out how the individual components of the complex upgrade contributed to the overall effluent water that outflows to the Tocó stream. This paper show analyses on suspended solids (SS), total nitrogen (TN), total phosphorus (TP), chemical oxygen demand (COD), and biological oxygen demand (BOD_5) parameters of WWTP performance and set ahead the following conception: in the test phase the overall efficiency raises despite the intermittent disturbances, yielding an acceptable level of purification.

EXPERIMENTAL

Beginning in summer June of 2010 started the test phase on this WWTP. Foremost it was intended to last for 6 months after finalization, but as the third digester's construction delayed, the test phase prolonged as well, giving further time for engineers to adjust. The reconstruction was finished in 2011 November, permitting successful operational conditions. Literally this date coincides with end of the test phase and the experiment as well. Samples were taken on every Monday of the second week of each month. The performance evaluation concentrates on overall efficiency of wastewater treatment (see Table 1.), thus the influent (D1) and the effluent (D2) water measured for parameters. D1 location was at the main sewage collector pit before screening, while D2 location was at the effluent water control measuring pit.

In situ we used WTW pH 315i device for pH and electrode potential [9], WTW cond. 340i device for measuring conductivity and temperature values. A Thermo Electron Orion 810 A+ was used for analyzing oxygen concentration and saturation.

In laboratory we performed nitrite, nitrate, orthophosphate determination from filtered samples, using filters of 0.45 μm pore size, and Shimadzu UV-265 FW Spectrophotometer was utilized. Methodology followed the accepted technique in Hungary [10, 11], which was proved to be reliable when proper dilution ratio was needed. Ammonium concentration determination was performed using distillation technique [12] buffered above pH 9.5 [13]. Kjeldahl nitrogen and total phosphorus measures were performed with the same method mentioned above for orthophosphate and ammonium respectively after digestion using VELP Heating Digester DK20. Suspended Solid values obtained as filtered contents were dried for four hours in WTB BINDER ED 53. Chemical Oxygen Demand was analyzed according to the generally suggested method with dichromate [14], while Biological Oxygen Demand was attained based on Winkler technique [15].

Council Directive 91/271/EEC of 21 May 1991 concerning municipal wastewater treatment straightforwardly discusses obligatory standards. At sensitive areas of Hungary, which may be exposed to eutrophication if protective actions are not done, even stricter regulation is applied. Ephemeral streams, such as the Tocó are highly sensitive to contaminations and eutrophication. Above 100.000 population equivalent value, the treated effluent requires achieving the following technical threshold: COD_{aCr} of 75 mg O/l, a BOD_5 of 25 O_2 mg/l, a TN concentration of 25 mg/l, a TP concentration of 5 mg/l, and a SS of 50 mg/l.

RESULTS AND DISCUSSION

Among the in-site measured parameters, only the temperature showed us some sorts of seasonality. To maintain the optimal biological processes the winter session requires additional heat injection. Providing sufficient energy intake made it possible to reach only as low as 13°C twice in the period. The pH ranged from 6.79 to 8.43 with means of 7.83 at the inflow site and 7.24 at the effluent site. Standard deviations were ± 0.28, 0.33, respectively. A subtle aptitude for acidification can be observed, though it is in range of acceptance, making no concern of trouble, and also justifies the lack of chemical regulation. The conductivity values show the amount of dissolved ions in water. They varied from 1218 to 2110 μS/cm, with means of 1971 at the inflow point, 1563 at the effluent point (standard deviations were ± 89, and 138 respectively). Redox potential level describes induced biological activities, and it is linked to the amount of oxygen delivered to the wastewater. This data ranged from -79.5 to 31 mV, with means of -46.01 mV at the influent, -10.27 at the effluent (standard deviations were ± 14.74 and 20.21 mV respectively). Dissolved oxygen concentration level variation was between 0.20 and 7.74, with means of 0.79 at the inflow and 3.87 at the effluent (standard deviations were ± 0.40 and 1.67 respectively). The effluent dissolved oxygen concentration is higher than industrial standard 2.00 mg/l suggestion [16] for degradation, and as matter of fact it is raising over time.

The data of SS content varied considerably from 8 to 778 mg/l, with means of 436 mg/l at the influent, 65 at the effluent (standard deviations were ± 197 and 100 respectively). The average efficiency of the treatment was 83%. Apart form 2011 April, in which the team encountered settling malfunctions at the end stage; results show great prospects for suspended solids retention as after this failure in April the following eliminations yielded generally above 90%.

TN ranges from 3 to 111 mg/l, with means of 85 at the inlet, and 19 mg/l at the effluent point (standard deviations were ± 16 and 5 mg/l respectively). The average treatment efficiency was 76%. The readily available inorganic ammonium ion concentration in the influent dominates over organic nitrogen concentration. The complex organic nitrogen content first goes through hydrolyses, resulting in further ammonium ions to be utilized. After this nitrification happens, that demands a considerable amount of oxygen concentration in order to transform ammonium ion to NO_2, NO_3, which is performed properly yielding above 97% of retention. The level of ammonium concentration retention is achieved in a rising tendency, pointing out that the nitrification process is abused in controlled management. According to this however, the amount of remaining nitrate concentration is increasing as well (Fig. 1), highlighting the incomplete bacterial activity in which denitrification occurs. Denitrification requires anaerobic environment for proper nitrate reduction. The manifestation of this failing reduction can be traced back to several events. The unsynchronized ratio of hydraulic residence time can be an option for this phenomenon. On the other hand, the amount of total oxygen concentration tendency is increasing; still it is not as significant to draw back the process, and to coincidence with the remaining nitrate concentration, suggesting it only partially causative. Overall TN removal efficiency throughout the test phase has the slightest increase; mainly this can be addressed for the relatively high initial results.

Total-Phosphorus (TP) ranges from 2 to 27 mg/l, with means of 11 at the inlet and 6 mg/l at the effluent site (standard deviations were ± 5, 3 mg/l respectively). The mean final retention capacity was 42%. It has the lowest performance of the plant, making it important to emphasize. The added ferric-chloride capability for chemical phosphorus precipitation is certain; this parameter resulted with a steep line of performance increase at the end of the experiment. The available phosphate concentration through the treatment is utilized by the bacterial mass for their constant growth. The inappropriate level of conditions result lower bacterial pollutant degradation, therefore organism are forced to rely on their own reserves to feed energy balance, releasing intermittent phosphate constituent from the ATP to ADP transformation to accumulate, and slows new cell production. The modified Bardenpho 3-stage configuration also adversely affects the TP performance if incomplete nitrate reduction occurs [17]. Definitely, the almost doubled effectiveness was obvious with such results, unfortunately future predictions marks even more effort to raise further retention capacity.

Meanwhile the COD data ranged from 38 to 1642 mg/l, with means of 642 at the inlet and 133 mg/l at the effluent (standard deviations were ± 411, 74 mg/l respectively). The mean final retention capacity was 72%. This shows the available amount of organic loading in wastewater that can be chemically oxidized, leaving behind more than fair amount of organic compound source, thus suppressing no bacterial growth by means of available carbon. Along with this, BOD_5 data followed identical tendencies (Fig. 2), ranging from 11 to 592 mg/l, with means of 292 at the inflow point, and 56 mg/l at the effluent point (standard deviations were ± 127 and 23 mg/l). The mean final retention capacity was 78%. Both parameters have a considerable tendency toward good performance, especially after a year period, from 2011 summer retention ability reached constantly above 80%.

CONCLUSIONS

With the recent technology improvement the capacity of WWTP in Debrecen is doubled. The more than one year long test phase contributed to increase mean final retention capacities. SS, BOD_5 and COD parameters achieved 25, 39 and 35 percent efficiency raise respectively. After a year of integration from 2011 June, we can see that the effectiveness begins to output consistently permanent results, yielding above mean overall results. Ammonium removal is good, despite the warningly increasing nitrate concentration, though TN regulation resulted in a mere 5% raise. The 80 percent efficiency increase in the case of TP value shed light on the long learning adjustment of what the operating staff achieved as they were trying to be cost effective. The plant is not equipped with technology to remove phosphorus only via biologically, so it is necessary to overdrive financial considerations to achieve elimination standards. Among the in-site measured parameters only the high dissolved oxygen concentration is to be noted, since the aeration stage is crucial in energy saving, thus improving this segment would also contribute to reliability. Testing the plant with fluctuating amount of wastewater is finished, for a while it has to compete with low hydraulic levels; operators are motivated to disconnect redundant reactors, as the implemented maximum capacity probably will not be utilized soon.

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Table 1. Treatment efficiencies of the WWTP on the summarized components in monthly order

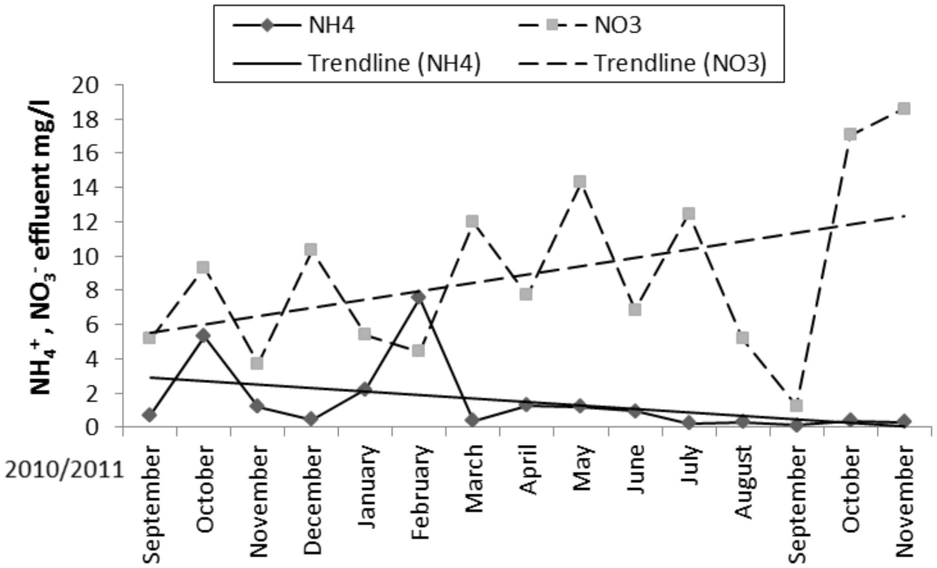
FIGURE CAPTION

Fig. 1. Dynamics of the effluent NH_4^+ and NO_3^- concentrations in mg/l accompanied with the respective trendline

Fig. 2. Dynamics of the increasing effluent COD and BOD_5 efficiencies with the corresponding trendline

Table 1. Treatment efficiencies of the WWTP on the summarized components in monthly order

2010 / 2011	Efficiency %				
	SS	TN	TP	COD	BOD_5
September	94,5	73,2	39,8	90,4	66,7
October	68,8	78,9	21,7	64,5	50,0
November	75,2	82,4	13,7	64,2	82,1
December	76,4	71,9	16,5	69,3	75,0
January	71,1	69,7	52,8	47,3	78,1
February	82,2	81,7	62,7	18,1	79,2
March	95,1	74,9	74,5	87,8	73,1
April	39,0	52,1	17,1	64,3	86,8
May	98,7	83,6	48,3	94,0	93,4
June	93,2	89,4	31,0	83,5	65,1
July	92,7	57,4	43,8	70,2	77,5
August	90,2	89,7	63,4	77,2	82,9
September	98,8	87,9	45,8	87,5	84,6
October	87,1	75,5	53,7	84,8	84,3
November	93,1	76,7	45,4	90,0	95,5
Mean	83,7	76,3	42,0	72,9	78,3
SD ±	15,9	10,8	18,7	20,1	11,5
Raise	25,7	5,4	80,0	39,3	34,3



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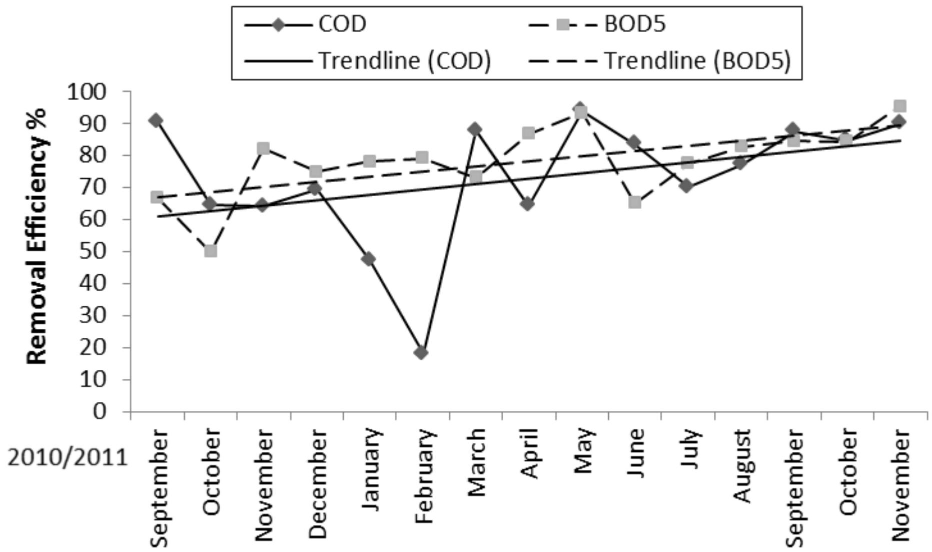

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