Comparative experimental studies for upgrading the Northpest Wastewater Treatment Plant

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Abstract With a hydraulic capacity of 200 000 m^3 d^{-1}, the Northpest Wastewater Treatment Plant is the largest wastewater treatment facility in Budapest, Hungary. At the relatively high influent nitrogen concentration of 60 mg TN l^{-1}, stable nitrification and efficient denitrification are required in order to meet the new effluent nitrogen criteria of 5 mg NH_4^+-N l^{-1} and 30 mg TN l^{-1}. The goal of the onsite comparative pilot-scale study was to elucidate the possibility of upgrading through chemically enhanced primary clarification (CEPT). The three experimental systems were connected directly to the influent of the primaries and used simultaneously during a five-week continuous-flow operating period. The COD concentration of the raw wastewater was typically in the range of 300-550 mg l^{-1}. Preclarified COD of the chemically pretreated wastewater proved to be 30-40 % lower than that of the reference system. However, the difference in the filtered COD was also considerable, in the range of 25-35%. The results verified the advantage of chemically enhanced preclarification in a cost-effective upgrading of nitrification. The procedure also improved the effluent quality regarding both COD and phosphorus concentration. However, decreased denitrification efficiency suggested that part of the necessary denitrifiable carbon source had also been removed in the primaries.

Keywords activated sludge, CEPT, denitrification, nitrification

Introduction and goals

The Northpest Wastewater Treatment Plant is the largest wastewater treatment facility in Budapest, Hungary, with a hydraulic capacity of 200 000 m^3 d^{-1}. Following the mechanical pretreatment units are Sedipac-type lamella clarifiers and fully aerated activated sludge basins. The current effluent nitrogen criterion is 27 mg NH_4^+-N l^{-1}, and neither nitrate nor TN is restricted. In order to protect the water quality of the Danube as well as comply with the EU guidelines, improvement of the nutrient removal performance has been decided as a treatment goal. Simulation studies showed that the new effluent nitrogen criteria of 5 mg NH_4^+-N l^{-1} and 30 mg TN l^{-1} would require stable nitrification as well as efficient denitrification due to the relatively high influent nitrogen concentration (60 mg TN l^{-1}).

The goal of the onsite comparative pilot-scale study was to elucidate the possibility of upgrading through chemically enhanced primary clarification (CEPT). CEPT helps to increase suspended solids removal prior to the activated sludge unit and thereby enhances nitrification by allowing for an increased SRT. However, it may also remove compounds that would support denitrification. Therefore, special attention has been paid to CEPT's effect on nitrification and denitrification. Three experimental systems were connected directly to the influent of the primaries and used simultaneously in a five weeks continuous-flow operation.

Methodology

Arrangement and operation of the experimental systems are illustrated in Fig.1. One of the two identically equipped activated sludge units received chemically pretreated influent. The anoxic reactor of the third system was divided into two stages. The influent of this system was also chemically pretreated. The pretreatment unit consisted of an intensively mixed tank (HRT=5min) and a slowly stirred flocculation tank (HRT=20min) preceding the clarifier. A Ferric(III)-Sulfate containing coagulant, Prefloc was used in two operational stages, initially at a higher concentration (45 mg Fe l^{-1}) and following the 18th experimental day at a decreased dosage concentration (27 mg Fe l^{-1}).

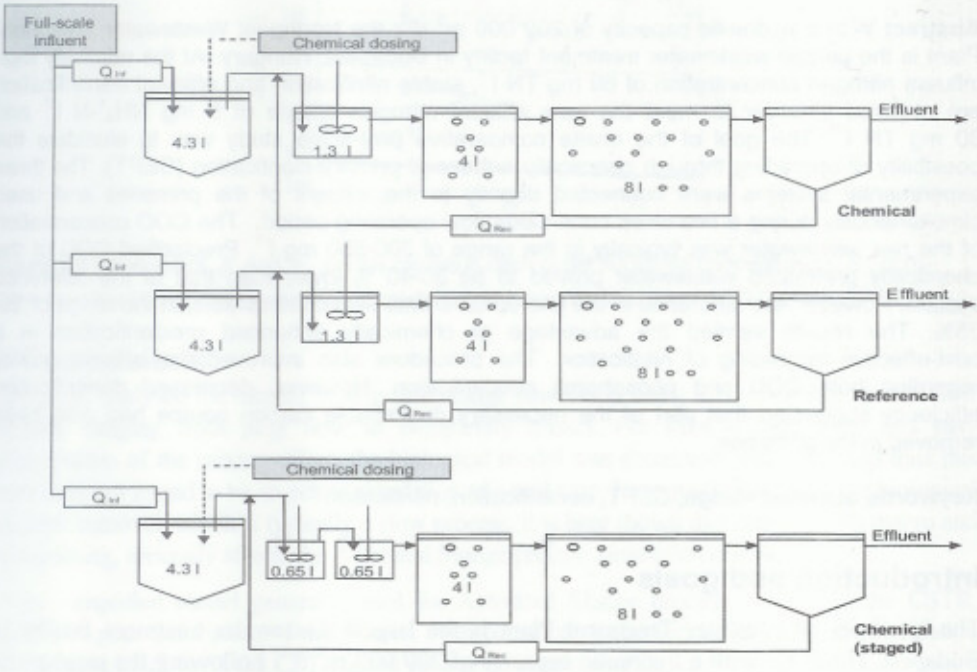

Figure 1. Illustration of the arrangement and operation of the three experimental systems

The operation was monitored through the measurement of temperature, pH and Dissolved Oxygen (DO) concentration as well as the concentration of Chemical Oxygen Demand (COD), filtered COD, Biochemical Oxygen Demand (BOD_5), Total Kjeldahl Nitrogen (TKN), ammonia, nitrate, nitrite, phosphate, total phosphorous, Total Suspended Solid (TSS), and Mixed Liquor Volatile Suspended Solids (MLVSS), and the Sludge Volume Index (SVI) was also measured. In order to keep similarity with the full-scale system, MLSS was maintained in a range of 2±0.5 g l^{-1} by removing appropriate amounts of the excess sludge. Due to the lower influent TSS concentration, the MLSS concentration stabilized at a lower value (2 g l^{-1}) in the chemically pretreated systems than in the reference system (2.4 g l^{-1}).

The temperature of the wastewater was in the range of 16-18ºC in the systems. The influent pH was in the range of 7.33-7.88 and, except for an accidental overdosing, decreased slightly to 6.1-7.2 as a consequence of the chemical pretreatment.

Results and discussion

The COD concentration of the influent wastewater was typically in the range of 300-550 mg l^{-1}. As illustrated in Fig. 2a., chemical pretreatment initiated an improved organic removal in the primary clarifiers. Preclarification efficiency of the reference system was 25-30 %, i.e. 50-150 mg COD l^{-1}, whereas 35-75%, (typically between 40-60%) of the influent COD was removed in the chemically enhanced primary clarifiers, representing an additional 35-100 mg COD l^{-1}. As a result, the preclarified COD of the chemically pretreated wastewater proved to be 30-40 % lower than that of the reference system. However, the difference in the filtered COD was also considerable, 25-35 %. The differences remained practically unchanged even after significantly decreasing the chemical dosage. In comparing data shown in Figs. 2.a and b, the characteristic difference for the preclarified COD proved to be detectable also in the treated effluent.

In the relatively low-load period, no significant difference could be observed in the nitrification efficiencies of the chemically pretreated and reference systems. However, chemically enhanced preclarification resulted in better nitrification performance at increased load (see Fig.3.). The rapid decrease of nitrification efficiency in the period of 04.18-04.25 in the system with CEPT and staged anoxic reactor can be attributed to the significant decrease of pH due to an accidental overdosing.

Fig.4. shows that in the chemically pretreated systems the effluent nitrate concentration of the anoxic reactors was higher than that of the reference system, i.e. denitrification efficiency proved to be higher in the reference system. This difference decreased with the reduction of the chemical dosage, suggesting that part of denitrifiable carbon source may also become precipitated in a CEPT system. Application of high dosages of chemicals should consequently be avoided in cases when the amount of carbon source is marginal compared to the demand of denitrification. This also represents the limit for upgrading nitrification performance through chemically enhanced primary clarification. The system with the staged anoxic reactor generally showed more effective dentirification in accordance with theoretical expectations (Plósz *et al.*, 2002).

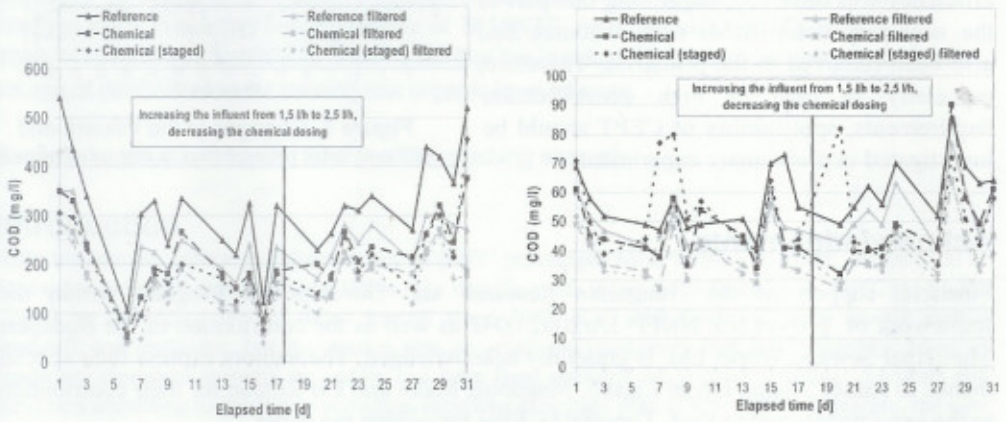

Figure 2. Changes in the (a) pre-clarified influent COD and (b) effluent COD during the experiment

As illustrated in Fig.5., the phosphorous concentration of the activated sludge influent decreased drastically due to the chemically enhanced primary clarification, and a significant

difference could also be observed in the treated effluent. In the systems with chemical pretreatment, the sludge volume index of the biomass stabilized at a low value. However, sludge settling ability slightly decreased in the reference system following the increase of the load.

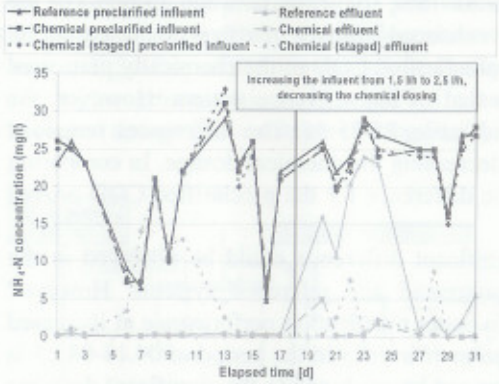

Figure 3. Changes in the NH_4^+-N concentration

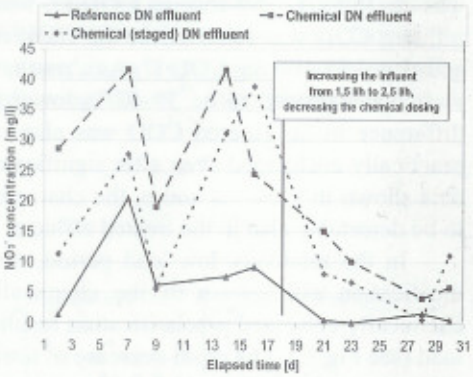

Figure 4. The NO_3^- concentration in the anoxic reactor's effluent

Conclusions

Results of the onsite experiment verified the advantage of the chemically enhanced preclarification in a cost-effective upgrading of nitrification. The procedure also improved the effluent quality regarding both COD and phosphorus concentration. With respect to denitrification ability, however, decreased efficiency was observed, suggesting that part of the necessary denitrifiable carbon source had also been removed in the primaries. Therefore, especially in case of high denitrification requirements, applicability of CEPT should be investigated in preliminary experiments.

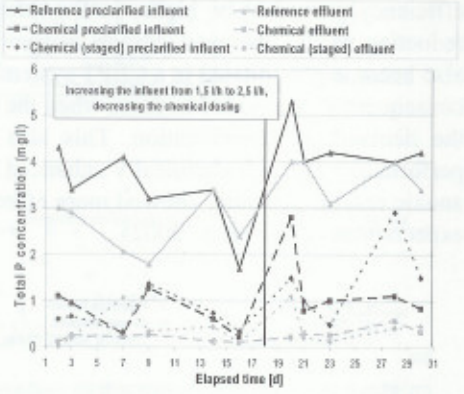

Figure 5. Changes in the influent and effluent total phosphorous concentrations

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