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EFFICIENT CONTROL OF COAGULANT DOSING IN WASTEWATER TREATMENT

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Introduction

With the advancement in online sensor development, as well as in the use of online control equipment, concepts and simulation software at water and wastewater treatment plants, the coagulation process is experiencing a significant growth in optimization. Compared with the traditional constant or flow-variable dosing which were the exclusive choices at most plants until few years ago, many plant owners are now open for modern and creative solutions. The growing concern on the plant process economy, efficiency as well as health and environmental concerns in the treated water has triggered research and development in this field. Thus, the Coagulant Dosing Control (CDC) has seen a radical change during the last decade.

The interrelationships between the water quality parameters as turbidity, suspended solids, phosphates, pH etc. and the optimum coagulant dosage are well documented. The need and the potential advantages are also well discussed [RATNAWEERA et al. 1994; LU et al. 2002]. DENTEL [1991] has presented a comprehensive review on CDC analysing the emerging approaches and their potential. A survey among Norwegian treatment plants revealed that 80% of Drinking Water Treatment Plants (DWTP)s and 83% Waste Water Treatment Plants (WWTP)s control their coagulant dosage either by flow proportional dosing or with a simple pH-overriding function ensuring the coagulation pH remains within a given range [RATNAWEERA 2004]. The objective of this paper is to present a novel technique to optimize the coagulant dosing control in WWTPs.

Methods

Using multivariate calibration concepts and related software, it is now possible to analyze the large amount of information [BEEBE, KOWALSKI 1987; MARTENS, NAES 1991]. For complicated processes like wastewater coagulation, which involves several variables, these tools are quite valuable. The proposed concept is based on partial least squares regression (PLSR) concept to establish relationships between coagulant ($FeClSO_4$) dosage (D), influent variables (X_{in}), and effluent variables (X_{out}) as illustrated in the equation below:

$$D = f(X_{in}, X_{out}).$$

We have conducted experiments in laboratory-scale and pilot-scale tests of wastewater coagulation to generate data series consisting with effluent parameters reacting to various dosages of different influent parameters. The laboratory-scale experiments were conducted using a semi-automated jar-test system, while the pilot-scale tests were performed in a 2 l/min reactor and reported elsewhere [RATNAWEERA et al. 1994]. Models wi'h feasible prediction abilities were developed. Further, the concept was tested on two full-scale WWTPs in Norway.

Toensberg WWTP is a medium scale WWTP with a design and connected capacity of 60 000 p.e. (person equivalent). However, due to heavy periodic discharges from food processing industries the organic load exceeds the design capacity. The treatment plant has grit chambers, input of septic waste, sand traps, flocculation chambers and six sedimentation tanks. The plant has two dosing pumps for the two separate lines. The plant uses empirical, flow proportional constants for each hour of the day with an effluent pH overriding function. The constants and the pH set points are adjusted according to the treatment results and past experiences.

Fredrikstad WWTP is a medium scale WWTP with a connected capacity of 75 000 p.e. The WWTP also receives industrial wastewater. The treatment concept consists of mechanical and chemical processes. The plant has only one process line, so the comparison is made according to the existing empirical dosing algorithm adjusted manually by the operators.

The experiments were implemented in two phases, where the process data were gathered to calibrate the model, and then to actively run with the new algorithm based on the calibrated model.

Results and discussion

The results from the laboratory scale experiments are summarized as model correlation coefficients given in Table 1. It demonstrates the weakness of the most common dosing concepts based on flow proportional systems.

Table 1; Tabela 1

Correlation coefficients of models with various influent parameters. Effluent quality is described using only turbidity (TUe)

Współczynniki korelacji modeli matematycznych przy różnych parametrach dopływu. Jakość odpływu opisano wyłącznie za pomocą wartości mętności (TUe)

Model structure; Struktura modelu	Correlation coefficient Współczynnik korelacji
Dosage = f(Q, SED, T, TUi, OPi, PHi, COi, TUe)	0.93
Dosage = f(Q, SED, T, TUi, PHi, COi, TUe)	0.91
Dosage = f(Q, SED, T, OPi, PHi, COi, TUe)	0.90
Dosage = f(TUi, TUe)	0.65
Dosage = f(Q, TUe)	0.62

Q flow; przepływ
SED sedimentation time, estimated as a ratio between flow and tank volumes; czas sedymentacji, określony jako stosunek przepływu do objętości zbiornika
TUi influent turbidity (NTU); mętność dopływu (NTU)
TUe effluent turbidity (NTU); mętność odpływu (NTU)
OPi ortho-P; ortofosforany (V)
COi conductivity; przewodnictwo właściwe
T temperature; temparatura
PHi pH

Using the influent, effluent and dosing data collected during the first phase, the model was calibrated for two WWTPs. The input variables were limited to flow and turbidity while the only effluent variable was the pH after coagulation. The model had a structure of D = f(Q, TUe and effluent pH). However, upper and lower pH setpoints were introduced to secure dosages during extreme conditions. The estimated dosages by the algorithm beyond these limits were doubled or halved, to keep the pH after coagulation within the normal levels.

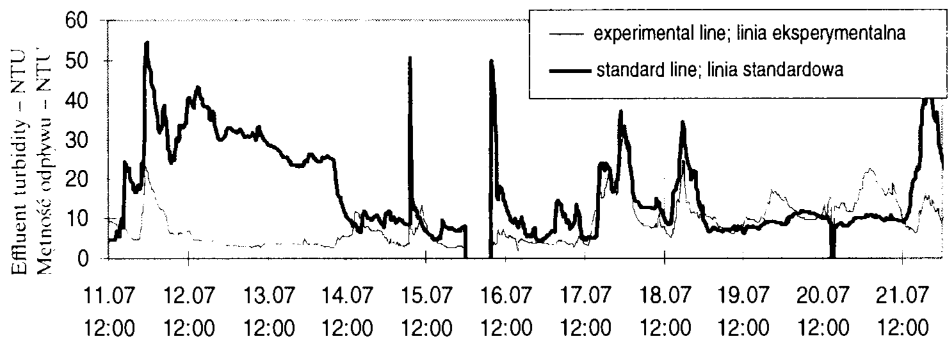

Fig. 1. Effluent turbidity of the standard and experimental lines at the Toensberg WWTP

Rys. 1. Mętność odpływu ścieków z linii standardowej i eksperymentalnej w oczyszczalni w Toensbergu (Norwegia)

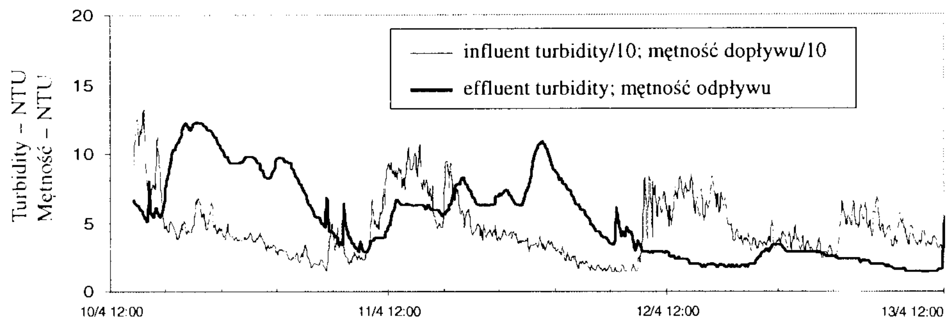

Fig. 2. Influent and effluent turbidity in the experimental line at the Fredrikstad WWTP

Rys. 2. Mętność dopływu i odpływu ścieków z linii eksperymentalnej w oczyszczalni w Fredrikstad (Norwegia)

Based on the influent and effluent data gathered during one week at the Toensberg WWTP, a simple model based on flow and influent turbidity was constructed. As mentioned earlier, the standard dosage at this WWTP is defined with variable flow proportional constants, which are based on previous experience. The plant personnel additionally adjust the constants depending on the effluent quality. Selected results are presented on Fig. 1, and shows that the effluent turbidity was more even and mostly below 10 NTU in the experimental line, while the standard line turbidity was often varied and higher.

Fig. 2 presents the initial results from the experiments at Fredrikstad WWTP. Despite the considerable variations in the influent turbidity, the experimental line has managed to keep the effluent turbidity below 10 NTU.

In both cases, the coagulant dosage was mostly less in the experimental line compared with the standard lines, although it was the opposite during periods. Higher dosages were required at times to keep efficient treatment levels.

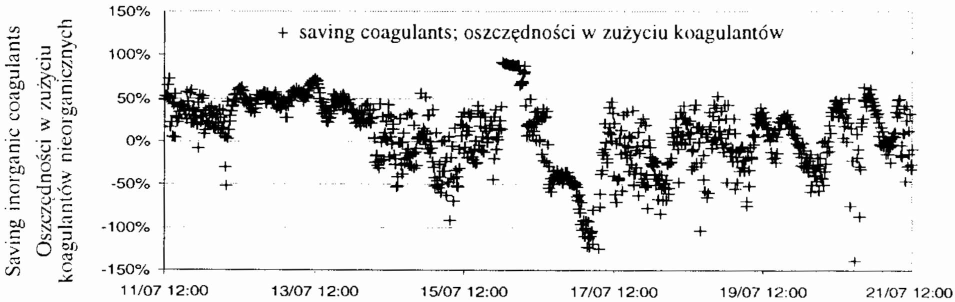

Fig. 3. Difference between coagulant consumption in standard and experimental lines at the Toensberg WWTP

Rys. 3. Różnica w zużyciu koagulantu na standardowej i eksperymentalnej linii ścieków w oczyszczalni w Toensbergu (Norwegia)

Fig. 3 presents the difference between dosages in the experimental and the standard lines at Toensberg WWTP, as the coagulant saving percentage. The average reduction of coagulants during experimental period was about 8% compare to the conventional dosing.

The full-scale experiments at these WWTP has verified the applicability of the concept to achieve more-even and improved effluent qualities, often with overall reductions in coagulant consumption. At present the tests are continued at Fredrikstad WWTP to calibrate and verify the model to widely varying flow rates due to rainy- and dry-seasons.

The way forward

This promising concept will soon be widely available as a commercial product in the market, following a Polish-Norwegian Research and Development venture. The concept is anticipated to be supported by the European Union. A consortium between the Polish consulting company Geomor-NIVA, the Chemistry Department of the University of Warmia and Mazury in Olsztyn, as the Polish academian partner and the Norwegian Institute for Water Research (NIVA) with its pioneer activities in CDC is established, and will be further strendthened by both Polish and Norwegian end-users.

Conclusions

Coagulant Dosing Control has gained a significant focus both in drinking water treatment and wastewater treatment during the last decade. Despite the reported success in the use of novel concepts in coagulant dosing control, the most plants still use the very basic concepts. Thus, the potential for improved coagulant dosing control still remains largely under utilized.

Using statistical data analysis, like PLSR, it is possible to construct various empirical models to predict the dosage based on selected influent and effluent data. The model structures are described. In two medium size WWTPs the validity of the concept was demonstrated. The saving of coagulants up to 8% was recorded in one of the WWTP for a given period.

A Polish-Norwegian Research and Development consortium will initiate a concentrate effort to provide the concept available to the market soon, providing great savings on coagulant costs, sludge management costs while securing better overall treatment efficiencies.

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Key words: wastewater, treatment, coagulant, dosing control

Summary

Coagulant dosing control (CDC) is necessary to ensure stable treated water quality and to reduce chemical costs both in drinking and wastewater treatment plants. The rapid development in online sensors and equipment as well as control strategies has triggered a significant development in CDC. Software sensors, streaming current detectors, charge titration units, potential dispersion analyzers etc. are now successfully used. Despite the significant advancement in the introduction and use of these novel techniques, most plants still relay on simple CDC techniques like flow proportional dosing, leaving great opportunities to reduce the coagulant costs, sludge treatment costs while achieving better treatment efficiencies overall. The paper presents a novel concept to optimize coagulant dosing control in wastewater treatment plants, and an intention to develop a widely available solution using a Polish-Norwegian Research & Development venture.

SKUTECZNA KONTROLA DOZOWANIA KOAGULANTU W OCZYSZCZANIU ŚCIEKÓW

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Słowa kluczowe: ścieki, oczyszczanie, koagulant, kontrola dozowania

Streszczenie

Kontrola dozowania koagulantu (KDK) jest konieczna w celu zapewnienia stabilnej jakości wody, jak i obniżenia kosztów zarówno w stacjach uzdatniania wody, jak i w oczyszczalniach ścieków. Wraz z wielkim postępem w strategii i technologii tzw. czujników „online" obserwuje się również znaczny rozwój w zakresie KDK. Zdecydowanie zwiększa się zakres czujników procesorowych, czujników w ciągłym przepływie, zestawów miareczkujących do oznaczania ładunku, analizatorów despersji itp. W przeciwieństwie do znacznego zaawansowania we wprowadzaniu i zastosowaniu tych nowatorskich technik, większość oczyszczalni ciągle opiera się na prostych systemach KDK, typu ciągłego dozowania proporcjonalnego, nie uwzględniając wielkich możliwości redukcji kosztów zużycia koagulantu i obróbki osadów, które istotnie wpływają na efektywność pracy oczyszczalni. Praca niniejsza przedstawia nowatorską koncepcję optymalizowania dawki koagulantu w oczyszczalniach ścieków oraz możliwości rozszerzenia dostępności tych rozwiązań w Polsce poprzez Polsko-Norweską Instytucję Naukowo-Rozwojową.

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