2SC5291 – Optimized biological treatment of urban wastewater

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Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27,00

Description

In urban wastewater treatment plants, biological processes are designed to eliminate carbon and nitrogen pollution through the action of microorganisms that grow spontaneously in aerobic or anaerobic environments.

The pollutants removed are concentrated in the form of aqueous suspensions or sludge, which constitutes bulky waste containing fermentable and toxic materials. The sludge management is therefore an important phase of treatment systems aiming to ensure the reduction of their volume and odour nuisance. One of the processes used for this treatment is anaerobic digestion, which produces liquids with a high concentration of nitrogen that must be re-treated. The amount of nitrogen contained in these effluents can represent up to 20% increase in the nitrogen load to be eliminated by the plant. There are two solutions to address this problem: (1) a so-called classical one, in which these concentrated effluents are directly returned to the primary plant, or (2) the anaerobic ammonium oxidation process, or Anammox, an innovative alternative to traditional nitrification/denitrification processes, allowing the direct transformation of nitrite and ammonium into gaseous dinitrogen.

The objective of this 'challenge week' is to develop control strategies for the two solutions mentioned in order to meet the minimum treatment requirements of the treated water and to compare their performance in terms of operating costs and biogas production as a vector for sludge energy recovery.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There are no specific prerequisites.

Syllabus

- Introduction on pollution, water and sludge treatment technologies.
- Presentation on the modeling of water treatment plants: focus on the formulation of the activated sludge reactor model and the moving-bed reactor (MBBR).
- Simulation of the classical process with constant and variable feed flow. Understanding of unit processes, impact of operating parameters on effluent composition, dynamics of microbial populations.
- Simulation of the Anammox process with constant and variable feed flow. Understanding of the functioning of unitary processes, impact of operating parameters on the composition of the effluent, dynamics of microbial populations.
- Proposal of PID regulation strategy in order to respect the imposed depollution specifications. Adjustment of the PID controller parameters by an empirical method of trial and error calibration. Evaluation of the quality of the controllers (static error, response time, overshoot, disturbance absorption).
- Comparison of the two processes on the basis of operating costs (additional carbon input and electricity consumption for aeration needs), sludge production and biogas production by anaerobic digestion.

Class components (lecture, labs, etc.)

The teaching team and the industrial partner will carry out a first session to introduce the problem. A presentation on the modeling approach of water treatment plants will be proposed with a focus on biological treatment reactors. Then, the students will be divided into teams. All the teams will work on the same specifications, so that they can deal with both process engineering and control aspects of the teaching.

Scientific articles and technical documentation will be provided for further study of the concepts covered. A written procedure for the empirical adjustment of PID parameters in the simulation software will also be provided.

Finally, each team will propose a control strategy to the partner, which will include the comparison and critical analysis of the two processes.

Grading

The evaluation is based on: continuous assessment, a written report, an oral evaluation.

Course support, bibliography

PDF support from the industrial partner

Reference books on control of bioreactors:

– Bastin G., Dochain D., On-line Estimation and Adaptive Control of Bioreactors, Elsevier, 1990.
– D. Dochain (éditeur). Automatic Control of Bioprocesses, Wiley-ISTE, 2008.

Documentation from Techniques de l'ingénieur:
– BOEGLIN J.C., Traitement biologique des eaux résiduaires, Techniques de l'Ingénieur, J3942 V1, Décembre 1998.
– BOEGLIN J.C., Traitements et dispositions finales de boues résiduaires, Techniques de l'Ingénieur, J3944 V1, Septembre 2000.
– GAÏD A., Traitement des eaux résiduaires, Techniques de l'Ingénieur, C5220 V1, Février 2008.
– SPERANDIO M., HERAN M., GUILLOT S., Modélisation biologique des procédés biologiques de traitement des eaux, Techniques de l'Ingénieur, W6500 V1, Août 2007.

Papers on Anammox process:
– NSENGA KUMWIMBA M., LOTTI T., SENEL E., LI X., SUANON F. Anammox-based processes: How far have we come and what work remains? A review by bibliometric analysis, Chemosphere 238 (2020) 1-17.
– VAN DER STAR W.R.L., ABMA W.R., BLOMMERS D., MULDER J.W., TOKUTOMI T., STROUS M., PICIOREANU C., VAN LOOSDRECHT M.C.M., Startup of reactor for anoxic ammonium oxidation: Experiences from the first full-scale anammox reactor in Rotterdam, Water Research 41 (2007) 4149– 4163.
– TAO C., HAMOUDA M.A., Steady-state modeling and evaluation of partial nitrification-anammox (PNA) for moving bed biofilm reactor and integrated fixed-film activated sludge processes treating municipal wastewater, Journal of Water Process Engineering 31 (2019) 1-9.
– LACKNER S., GILBERT E.M., VLAEMINCK S.E., JOSS A., HORN H., VAN LOOSDRECHT M.C.M., Full-scale partial nitritation/anammox experiences – An application survey, Water Research 55 (2014) 292-303.
– BIASE A., KOWALSKI M.S., DEVLIN T.R., OLESZKIEWICZ J.A., Moving bed biofilm reactor technology in municipal wastewater treatment: A review, Journal of Environmental Management 247 (2019) 849–866.
– VEUILLET F., LACROIX S., BAUSSERON A., GONIDEC E., OCHOA J., CHRISTENSSON M., LEMAIRE R. Integrated fixed-film activated sludge ANITATMMox process – a new perspective for advanced nitrogen removal, Water Science and Technology 69.5 (2014), 915-922.

Resources

– Software tools: SUMO, Complete simulator of the classical treatment plants
– Documentation describing the unitary treatment processes (wastewater and sludge)

– Supervision:

  o Teaching staff: Cristian Puentes (associate professor, CS, LGPM), Sette Diop (researcher, L2S), Nicolas Brunet (PhD student, CS, LGPM)

  o Industrial partner

Learning outcomes covered on the course

At the end of the Challenge Week, the student will be able to:

– Simulate an urban wastewater treatment plant with treatment of secondary effluents or sludge.

– Understand the operation of the Anammox process as an alternative to the traditional treatment of nitrogen pollution.

– Design PID control loops to maintain the system at desired operating conditions (regulatory requirements on nitrogen and carbon concentration).

– Determine and critically analyze the best solution for the treatment of effluents with high ammonia concentration in terms of operating costs and sludge energy recovery.

Description of the skills acquired at the end of the course

– C1.1, Analyze: study a system as a whole, the situation as a whole. Identify, formulate and analyze a system within a transdisciplinary approach with its scientific, economic, human dimensions, etc. Milestone 1

– C1.2, Modeling: using and developing the appropriate models, choosing the correct modeling scale and the relevant simplifying assumptions. Milestone 2

– C2.3, Identify and independently acquire new knowledge and skills. Milestone 2

– C4.2, Propose one or more solutions answering the question rephrased in terms of value creation and complemented by the impact on other stakeholders and by taking into account other dimensions. Quantify the value created by these solutions. Arbitrate between possible solutions. Milestone 1

– C7.1, Basically: Structure ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created). Milestone 2

– C7.2, On the relationship with others: Understand the needs and expectations of his interlocutors evolutionarily. Encourage interactions, be a teacher, and create a climate of trust. Milestone 2