Détermination d'indicateurs pour comprendre et prévenir les problématiques de colmatage dans les filtres plantés de roseaux à écoulements verticaux

Determination of indicators to understand and prevent clogging problems in vertical flow constructed wetlands

Context:

Optimized water management in urban, rural or industrial environments is a challenge for communities today. Treatment wetland is a nature-based technology to treat domestic wastewater from small communities. It is particularly well developed in France with around 5000 plants in operation. Over the years, the process has proven its efficiency and reliability. However, increasingly stringent regulations impose to continuously improve treatment performance. Due to their design, French Vertical Flow (VF) treatment wetlands accumulate a complex mixture of mineral and organic matter in the form of a sludge deposit at the surface and within the filter. Understanding the processes of filtration and biodegradation in French VF treatment wetlands is of great importance to avoid system dysfunction such as clogging in the short term and to define design and operation modes that ensure long life expectancy of the systems.

The processes governing the formation and evolution of the sludge deposit layer are typical of a biotechnosoil. In a previous study, analytical methods were adapted to this specific media. The X-Ray Diffraction (XRD) used for crystalline mineral phases characterization required specific treatment to account for high organic contents. Respirometric assays were found to be good indicators of stability of the organic matter (OM). Fractionation protocols were recommended to assess the extractability of the particulate OM. Humic- and fulvic-like substances analyses had also often been used to characterize stabilization or maturation of the OM, they can be complemented by spectrometry, thermogravimetry (TGA), and differential scanning calorimetry (DSC) methods. Finally 3D Fluorescence EEM spectroscopy on the soluble extracts provide valuable additional information on the nature, complexity and aromaticity of the molecules in the OM.

The heterogeneity of sludge deposit accumulation within the filter can be observed at different scales. At the pore scale, thin sections and X-ray tomography reveal how deposit not only accumulates on gravel surface but also in the bulk of the porosity and provide fine metrics to measure the fouling. In-situ profiles combining cone penetrometry and geoendoscopy provided qualitative information on the degree of fouling over the entire depth of the filtration layer. Finally, the distribution of sludge deposit over an entire filter was assessed by electromagnetic induction mapping.

The growth of this layer over the years of operation also largely contributes to the performances of the system. But it also represent a potential source of clogging. Currently, there is still a lack of knowledge on the determinant parameters controlling clogging. In order to optimize treatment performances over the long term, the processes occurring within this deposit must be better understood. Integrated tools and methods must be developed or adapted to treatment wetlands specificities to describe and monitor them.

Work description:

The work will be carried out in collaboration between DEEP laboratory in INSA Lyon (https://deep.insa-lyon.fr/) and REVERSAAL research unit from INRAE Lyon (https://reversaal.inrae.fr/) as part of the work of the joint research cluster in environmental engineering RESsourcEs Eaux & Déchets (RESEED, https://www.reseed-lyon.fr/). The work is a continuation of Manon Kania's PhD on the biophysicochemical characterization of organic matter (https://www.theses.fr/2018LYSEI045) and German's work on the 3D imaging of these deposits.

The thesis work will essentially focus on understanding the sequence of biodegradation processes that lead to clogging and to quantitatively determine the environmental conditions that favor it. To achieve this goal, the PhD candidate will use a combination of investigations of specific clogged full-scale treatment wetlands and long-term observation of clogging phenomena on a 20 m^2 pilot equipped with dedicated sensors (REFLET research platform), as well as laboratory experiments. The coupling of advanced biophysicochemical analyses of the organic matter and the associated description of the porous medium at pore scale should allow to better understand clogging processes and build specific predictive models to better precise design and operation modes.

From an operational point of view, the thesis work will have to make it possible to determine the organic and hydraulic limits to prevent and control clogging in order to improve the sizing of the systems. Ideally, the work should develop relevant indicators and/or measurement tools to assess the evolution of clogging for prediction purposes. The thesis will rely on the ongoing EVEREX project with the FEVE (http://f-e-ve.fr/) that aims at building a large database of treatment wetlands design characteristics as well as treatment performances.

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PhD Candidates:

Candidates with a background in chemistry, geochemistry, biochemistry, chemical and/or process engineering and environmental science are encouraged to send their CV.

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