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Monitoring of water processes using intelligent condition indicators

Mika Liukkonen* Yrjö Hiltunen**
Ilkka Laakso* Petri Juntunen******

**Department of Environmental Science, University of Eastern Finland, P.O. Box 1627, 70211 KUOPIO (Tel: 358-40-3510644; e-mail: mika.liukkonen@uef.fi).*
***Department of Environmental Science, University of Eastern Finland, P.O. Box 1627, 70211 KUOPIO*
****Stora Enso Fine Paper, Oulu, Finland*
*****Kuopio Waterworks, Kuopio, Finland*

ABSTRACT

Water quality is an increasingly important issue, because water is the mostly used raw material in the world and poor-quality water causes many difficult issues in societies and ecosystems. Industrial wastewater treatment, for instance, is facing big challenges concerning fulfilment of both general and plant-specific regulations concerning their effluents and cost management of treatment plants. The wastewater coming from the pulp and paper industry contains substances such as nutrients (phosphorus, nitrogen) and solid organic material, which in large quantities are considered harmful to the ecosystem, so competent treatment is required and the treatment efficiency has to be monitored and controlled carefully and continuously. Nonetheless, it seems that the overall operation of the treatment plants needs to be improved, if the water industry is to satisfy regulations for increased efficiency (O'Brien et al., 2011).

Monitoring and control of wastewater treatment relies a great deal on the availability of accurate and reliable sensor information. Because of the difficult environment, only a part of the process variables can be measured continuously using relatively simple and inexpensive physical sensors, whereas the determination of certain quantities of interest requires costly laboratory analyses which cannot be performed online (Valentin & Denoeux, 2001). Therefore, it is obvious that forecasting process outputs such as discharge would offer a way of achieving better control of wastewater treatment and computational elements such as soft sensors can provide valuable tools for process monitoring. Model-predictive control of dissolved oxygen in the activated sludge process, for example, has been observed to provide significant benefits compared with the previously applied control system (Holenda et al., 2008; O'Brien et al., 2011). However, it seems that controllability is still an open issue in the water industry and due to the lack of other opportunities the common focus will be on aeration control (O'Brien et al., 2011).

A generic piece of software for monitoring water treatment processes has been presented earlier (Liukkonen et al., 2013). One possibility to perform model-based process monitoring would be to combine the basic online monitoring software with an offline modelling tool (See Fig. 1), which can be used for creating model-derived condition indicators to be shown on the screen of monitoring tool. The modelling tool makes it possible to add computational condition indicators to predict the trends of discharge concentrations or variables indicating the quality of treated water, and show them on the screen also. These intelligent condition indicators can then be followed in the monitoring tool just like the other measurements. The system is demonstrated in a wastewater treatment environment by using process measurements from an activated sludge treatment plant, which is part of a pulp and paper plant. The plant treats 300–500 l/s of waste water on an average.

The modelling tool involves currently a regression-based variable selection module, which can be used for creating variable subsets to be used in predictive models. After this procedure, the five selected variables are used for creating a model to predict the future COD rate (See Fig. 2). The developed condition indicator can then be added to the monitoring tool, as is shown in Fig. 3. It is remarkable that although multiple regression is used here as an example, the model can basically be of any type.

In this example, the gained empirical model for the instantaneous chemical oxygen demand (COD) is as in (1) (See Fig. 2):

$$COD \approx 0.577*COD_0 + 0.017*F_{c1} + 0.003*C_{CB} + 0.051*F_{EC} - 0.102*O2_A - 1.815 \quad (1)$$

where COD_0 denotes the previous chemical oxygen demand (t/d), F_{C1} is the symbol for the total wastewater flow in channel 1 (l/s), C_{CB} is the conductance in the batch cooking channel (mS/m), F_{EC} stands for the flow of the condensates from the evaporator (l/s), and $O2_A$ denotes the amount of dissolved oxygen in the aeration pool (mg/l).

Challenges such as tightening legislation regarding to pollutants, pressure to increase the energy efficiency of treatment, and influents that are increasingly demanding in terms of stable and efficient treatment, are typical for industrial wastewater treatment. Monitoring systems capable of alerting when there is a drift towards an undesired or dangerous condition are useful, but a monitoring system of today should be able to assist the personnel to interpret the prevailing, and more importantly, the future risk level from the measurements.

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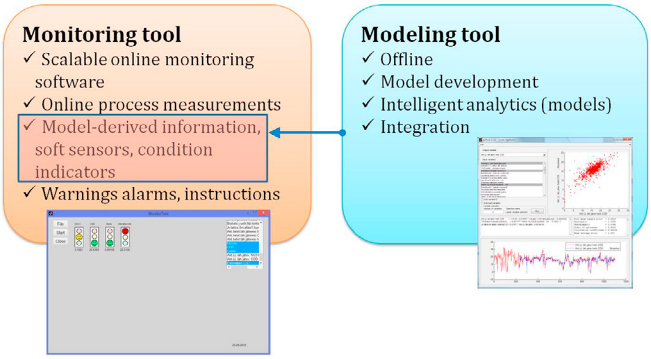

Fig. 1. The combination of monitoring and modelling tools.

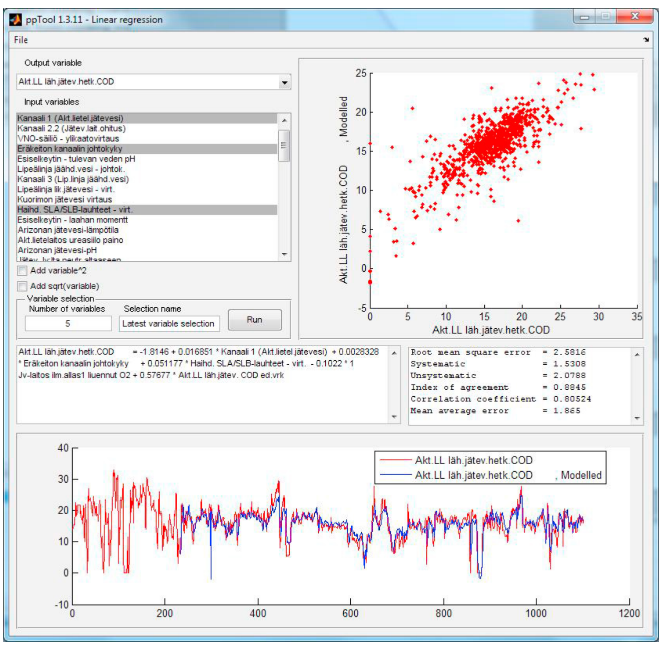

Fig. 2. The developed COD model in the model tool using the selected variables.

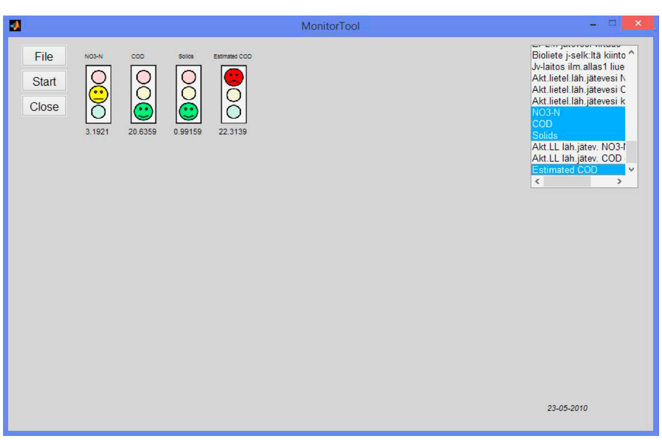

Fig. 3. The monitoring tool showing condition indicators for nitrate-N (kg/d), COD (t/d), suspended solids (t/d) and the estimated future COD rate (t/d).

A potential future application of the software is presented in Fig. 4. Intelligent condition indicators would improve the efficiency and flexibility of monitoring in wastewater treatment plants.

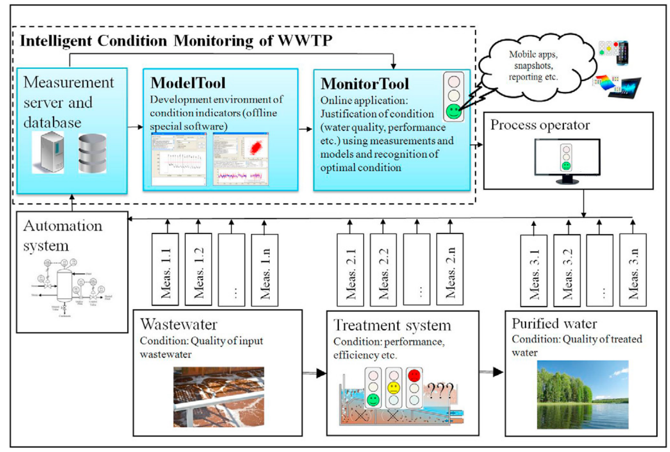

Fig. 4. Future scenario of the intelligent condition monitoring of wastewater treatment.

In summary, industrial wastewater treatment is a challenging process to control and requires sophisticated monitoring tools that can provide more advanced diagnosis and prediction capabilities. A sophisticated monitoring tool able to perform analyses and visualization of multivariable measurement data, alert in problematic situations, and provide instructions in problematic occurrences is essential for the management of water treatment. A model-based monitoring system based on specifically designed knowledge extraction and diagnostic techniques can support a decision-maker by analyzing recent process history and extracting the essential information, which can be used in predictive model-based monitoring.

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